VOL. 36, NO. 7 JULY, 1959

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Published Monthly by the AMERICAN JOURNAL OF OPTOMETRY PUBLISHING ASSOCIATION.
1508 Foshay Tower, 821 Marquette Ave., Minneapolis 2, Minn.

ANNUAL SUBSCRIPTION, UNITED STATES and CANADA $8.00; FOREIGN $9.00.
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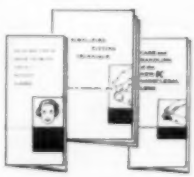

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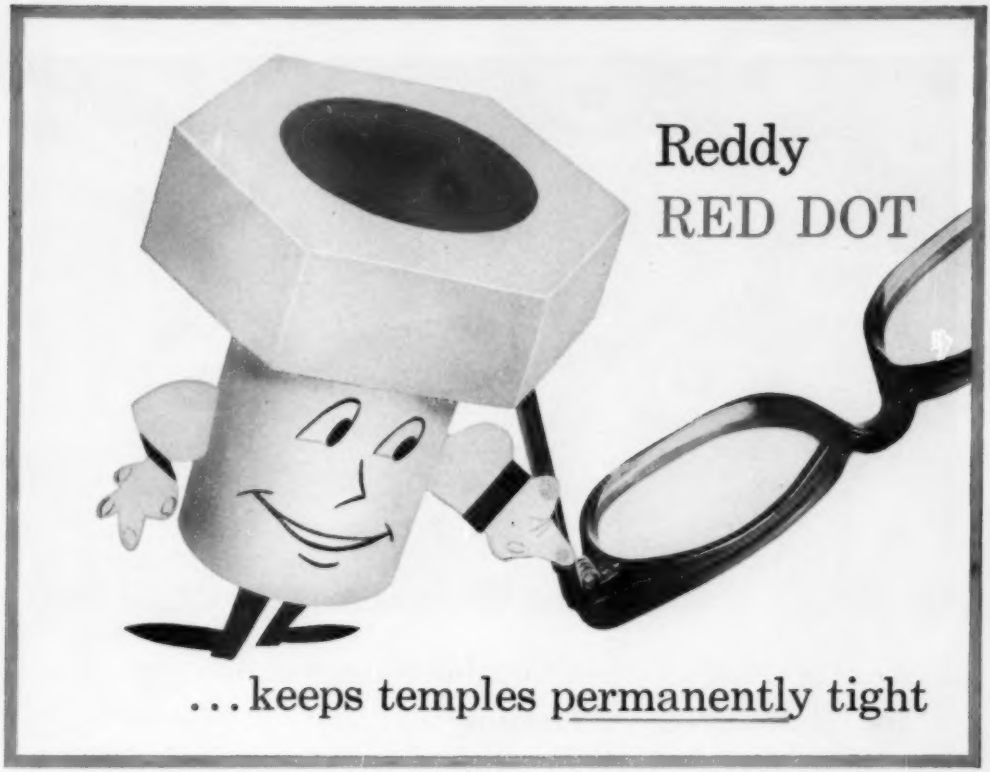

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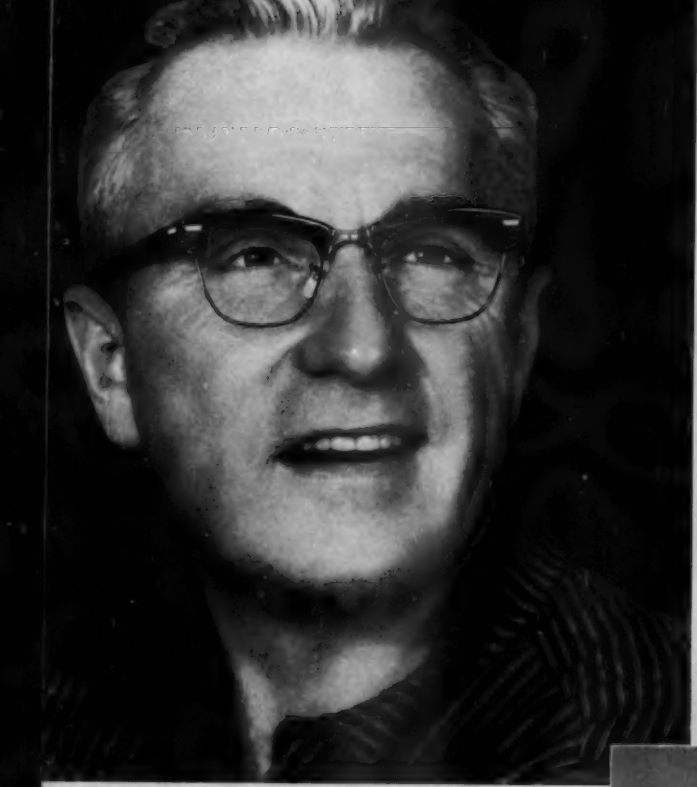

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THE USE OF GRAPHIC ANALYSIS IN VISUAL TRAINING*

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A solid foundation for the systematic organization of our knowledge about visual functions began to be laid in 1864 when Donders[1] introduced the graphical method of analysis of the relationship between accommodation and convergence. Widely used over the years since that time, its application to orthoptics was greatly simplified in 1943 with Fry's[2] description of five "fundamental variables" in the accommodation and convergence relationship which corresponded to easily recognized features of the graphically plotted zone of clear single binocular vision. With Hofstetter's[3] detailed description of the characteristics of the zone of binocular vision only two years later, a broader and clearer understanding of the principles and limitations of visual training was at hand. Since that time a number of papers have extended the applications of graphic analysis in orthoptics work.

These applications are set forth most explicitly in three papers by three authors. In one of these, Hofstetter[4] has described a method for the graphical specification of the type and degree of orthoptics training, a method which eliminates the necessity of detailed instructions regarding procedure and which facilitates the transfer of procedures from one instrument to another. Basically the method consists of drawing arrows on the graph, the direction, position, and length of the arrows indicating unequivocally the precise stimulus values to be employed in training. Such knowledge of the required stimulus conditions is sufficient to permit the orthoptist then to employ any of a number of instruments or to devise entirely new exercises to accomplish the desired training. To illustrate the application of this method, Hofstetter considered ten different conventional training techniques and showed how each could be represented graphically, together with the desired target distance, lens, and prism requirements.

Another paper, by Schapero,[5] described ten basic types of visual

*Read before the annual meeting of the American Academy of Optometry, Section on Orthoptics, Boston, Massachusetts, December 15, 1958. For publication in the July, 1959, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

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training problems by means of graphic analysis. Schapero's approach was both diagnostic and prognostic. Analyzing each case in terms of high, low, or normal tonic convergence, high, low, or normal ACA ratio, and sufficient or insufficient fusional convergence, he showed how to determine the fundamental source of the problem, the likelihood of overcoming it by orthoptic training alone, and the most efficient training procedure and/or lens-prism formula to utilize in alleviating it. The theoretical basis of Schapero's classification is derived from Fry's description of the fundamental variables and from Hofstetter's elaboration of zone characteristics. It thus perhaps assumes a degree of validity for the data of the routine examination which may often not be achieved, particularly in patients with severe visual problems. In the absence of indications of non-validity of the data, however, Schapero's classification is probably the most direct method of analyzing the visual difficulty and determining the best course of action.

Flom,[6] in another paper, has extended the usefulness of this technique by identifying various anomalies of the graphical zone of clear single binocular vision in terms of malfunctions of the sensory, integrative, and motor processes involved in vision. In so doing he has discussed several manifestations of what, in terms of Hofstetter's investigations of the zone, might be considered invalid data. For example, Flom points out the frequent finding of a markedly narrow zone of clear single binocular vision when a patient with previously uncorrected anisometropia is first examined. In a direct analysis of such a zone, it would seem necessary to incorporate prism or to alter lens power in order to satisfy Sheard's or Percival's criterion, or alternatively, it would seem necessary to embark on an orthoptic program aimed at widening the zone. However, it is nearly as frequently found that after wearing the unmodified new lenses for a short time—a few hours or a few days—the patient will demonstrate a markedly widened zone whose limits fulfill all criteria for adequacy. The rapidity with which such changes occur without special orthoptic attention suggests that the observed widening is not due to a physiological change in the functional limits of fusional convergence, but instead represents "truer" measurement of the abilities already possessed by the patient—abilities which were not fully elicited in the first examination because of the unusual stimulus conditions. If this be the case, then one could say that the original data were invalid, insofar as the tests did not in fact measure the functions which they were designed to measure, and that either the patient was not a "good observer" or the test procedures were not adequately controlled. The "poor observer" hypothesis

can often be rejected on the basis of good reliability, i.e., repeatability, of the original data. This leaves the test procedures and the refractionist himself as the potential culprits—culprits, that is, if we consider the gathering of invalid data to be a culpable offense, which, as we shall see, it may not always be.

Refractionists typically adopt a fairly standard routine for testing most of their patients. In settling on the routine that suits them best, they also adopt phrases to use in giving instructions about the test. The phrases may not convey the same information to one patient as to another, and this frequently affects the test results. Where findings appear improbable, repetition of the test with rephrasing of instructions will frequently lead to a different and more likely result. Thus the refractionist's methodology, even when employing highly standardized test procedures, plays an important role in determining reliability and validity of the data.

A great deal of time and effort has been expended on design of targets for specific tests in hopes of finding the "best" target, by which is usually meant the target which will permit the test to be performed in a minimum time with maximum accuracy. Similarly, many investigations have been directed toward establishing the "best" techniques to be employed in the various tests, "best" again generally meaning minimum time and maximum accuracy. In both cases, the meaning and measure of accuracy is usually the reliability of the test result rather than its validity, though it should be noted that so far as many of the optometric tests are concerned, validity is reasonably well assured by the design of the test procedure itself, providing reliability is high and providing the known discrepancies between stimulus and response are taken into account.

It is in this last-mentioned factor, however, that several large pitfalls may be found. The data of optometric tests are the recorded values of lens and prism powers. As such, they represent *stimulus* values. Visual problems arise, however, among other causes, from the interrelationships of the accommodative and convergence *responses*. Convergence responses, i.e., the relative directions of the visual axes, can be determined quite easily by objective or subjective means and nearly always agree closely with the stimulus values. Accommodative responses have considerably greater latitude because of depth of focus, and so may depart considerably from the stimulus magnitudes. The accommodative status can be measured quite accurately by various objective or subjective techniques, but the typical visual acuity test is not one of these accurate techniques. It is usually assumed, however, that ability to read a line

of small letters indicates that the accommodative response closely approximates the stimulus, and so analysis of the visual problem is made on the basis of the recorded stimulus values. Presumably then, the "best" targets and techniques would be those which assured that stimulus and response were approximately equal, thus giving a high degree of validity to the test and to the usual assumption of near-equality.

This point of view, however, neglects the fact that the visual targets confronting the patient in his everyday activities are certainly no more efficient, probably much less, in evoking accurate accommodation than is the Snellen chart or the optometric near-point card.

To devise "better" targets or procedures, or even to devise techniques which measure responses directly, might well defeat the purpose of the examination. Knowledge of the precise characteristics of the "built-in," i.e., physiological, relationship between accommodation and convergence for a given patient would of course be desirable in evaluating his visual problem. If his problem stemmed, however, from a lack of facility in the control of accommodation, from a strong tendency toward under- or over-accommodation for targets at various distances, or from a poor quality of either sensory or motor fusion, the data of the "better" tests would not reveal the deficiency. So, the "poorer" tests may well be the better ones after all, and the invalid data the more informative.

It is in the assessment of the validity of optometric data that graphical analysis possesses outstanding advantages and has become a powerful analytical tool. Its use in this way, and the merits of following the progress of orthoptic training by graphical techniques are illustrated in a case described by Heath and Hofstetter[7] in which two years of training were shown to have produced no real quantitative changes in the data, but only a marked improvement in validity and reliability. The multiplicity of internal checks on the data provided by the graphical technique in most cases permits ready identification of invalid and/or unreliable single findings or sets of findings. Having so identified various findings the optometrist is not led to an erroneous conclusion regarding the nature of the visual problem. In most cases it is not even necessary to re-test the patient to establish the "true" values of the faulty test findings for these, too, can readily be approximated by means of known relationships between the tested visual functions. Having thus established the graphical pattern of the zone a direct analysis of the visual problem can then be made by applying the appropriate criteria to the rectified zone.

Though these procedures might appear to persons unfamiliar

with graphical analysis to constitute an extremely presumptuous manhandling of the carefully-taken optometric test data, it should be emphasized that these procedures are based on a sound and thorough knowledge of the characteristics of the relationship between the two functional variables involved, namely accommodation and convergence. To accept the individual test findings at face value would be to ignore this body of knowledge and to place one's faith in the adequacy of the test procedure and the total compliance and accurate response of the (often bewildered) patient.

It has been the writer's observation, however, that full utilization of the reliability- and validity-checking features of graphic analysis is seldom made. Indeed, in routine use only the most elementary and direct analysis is often attempted. Many inferences which might properly be drawn regarding the nature of the visual problem are never drawn, for two reasons: (1) because of the well-established direct analytical procedure of disregarding obviously invalid or unreliable data, and (2) because Hofstetter's careful studies of zone characteristics have led to the widespread opinion that certain of the routine test findings have little bearing on the patient's efficiency and comfort and are too susceptible to the vagaries of the patient's interest and volition to be useful in analysis anyway. This has given rise to the somewhat incongruous situation, for example, of the optometrist carefully taking and recording blurs, breaks, and recoveries and then disregarding the breaks and recoveries in his analysis. Or, another example, the monocular and/or binocular cross-cylinder tests may be performed at near and their values recorded, but this information is then ignored because no conventional symbol is available for plotting these findings on the graph, nor has the relationship of these tests to the others used in determining the zone been well enough established to incorporate them into the general system of analysis.

Though it may indeed be true that breaks and recoveries are much less reliable than blurs, and that they are so greatly influenced by the patient's set and the refractionist's prism-handling as to be quantitatively meaningless as indices of functional abilities, there are still useful interpretations of these findings which can be made through internal comparisons. These interpretations must be governed by the supposition that the factors which influence the findings in unpredictable fashion remain approximately constant during a given examination of a particular patient. This supposition is subject, in each case, to verification by the usual procedures of estimating validity and reliability.

To demonstrate this use of what might be termed "inferential

graphic analysis" as a supplement to the more conventional "direct graphic analysis," a number of cases have been selected to illustrate types of problems which have been referred to the Orthoptics Clinic of the Indiana University Division of Optometry for visual training.

In case No. 1 (Figure 1-A), when attempts are first made to connect the appropriate findings by lines in order to establish the limits of the zone of clear single binocular vision it becomes apparent that some of the findings must be in error to yield a zone of such aberrant shape. Plotting the breaks and recoveries shows that they give limits with approximately the same slope as those of the ductional blurs and the phorias (Figure 1-B). Immediately then it is seen that the minus lens to blur was almost certainly a faulty finding. It may be only coinci-

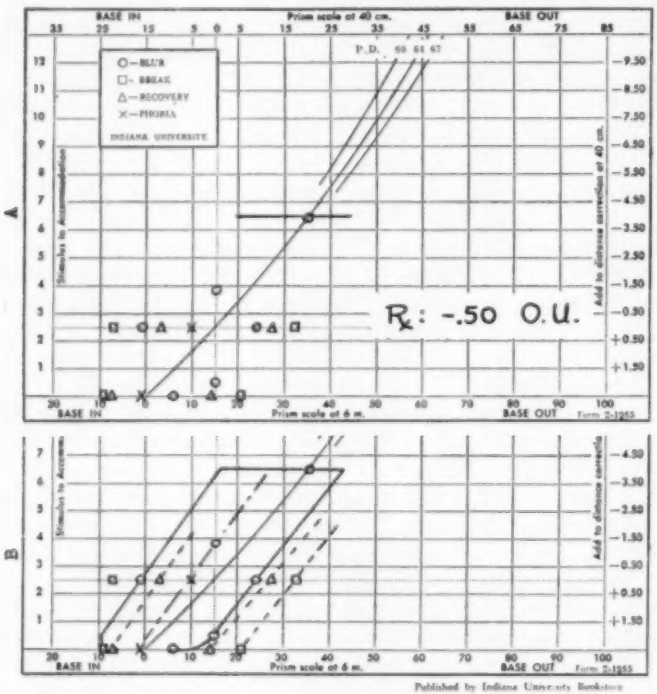

Fig. 1. (a) The examination data of Case 1 plotted in the conventional manner before outlining the zone of clear single binocular vision. Connecting the blur findings would show a zone of aberrant shape. (b) The zone outlined after considering the slope indication of the breaks and recoveries, as well as the blurs and phorias.

dental that the plotted blur finding falls on the extension of the phoria line, but one could reasonably infer from this that the patient accommodated in response to the minus lenses only so long as positive fusional convergence was simultaneously called forth. To accommodate for more than 1.25 D. of minus lens power at 40 cm. would have necessitated the use of negative fusional convergence to maintain single vision. This the patient failed to do. Instead, he apparently preferred to accommodate less in order to continue using positive fusional convergence to avoid diplopia even though the under-accommodation caused the target to blur. Repetition of the test with more careful instructions would likely show an increase of perhaps 2 D. in this finding.

Disregarding the faulty finding, inspection of the zone shows that Sheard's criterion is barely fulfilled at 40 cm., and is not fulfilled at any closer distances. Without lenses, Sheard's criterion was fulfilled only beyond about 1½ meters. Thus the therapy of choice is prescription of the refractive correction for constant wear. An orthoptics program in addition to the correction lenses is not strongly indicated, though there is little doubt that it would hasten adaptation to the new lenses and, by widening the zone, provide a greater margin of comfort at near and extend the proximal limit of the comfort range. It could also be assumed that these changes would occur, though more slowly, without orthoptics but with continuous wearing of the correction lenses.

Case 2 (Figure 2-A) is remarkable because the phoria and blur data were so nearly identical to Case 1, yet the solution was radically different. Taking the breaks and recoveries into account indicates a high ACA ratio (Figure 2-B), instead of the low-normal ACA ratio found in Case 1. Here it can be seen that the only finding seriously in error was the near phoria. This can be accounted for on the basis of a failure by the patient to accommodate fully for the 40 cm. target distance. Another possibility is that it was due to a fusional movement exerted by the patient as a result of the habitual necessity of overcoming his esophoria at near by strong use of negative fusional convergence.

On the basis of this zone it can be seen that the refractive correction should provide an adequate solution to the patient's difficulties which stemmed from an excessive esophoria at near with inadequate negative fusional reserve. There is little likelihood that orthoptics alone would be able to relieve the problem, for it would be necessary to widen the negative side of the zone about 8-9Δ to achieve Sheard's criterion without lenses. Percival's criterion, less often used, would require only 3Δ increase in the negative side of the zone, provided the positive side remained unchanged: more if the positive side increased as it would be

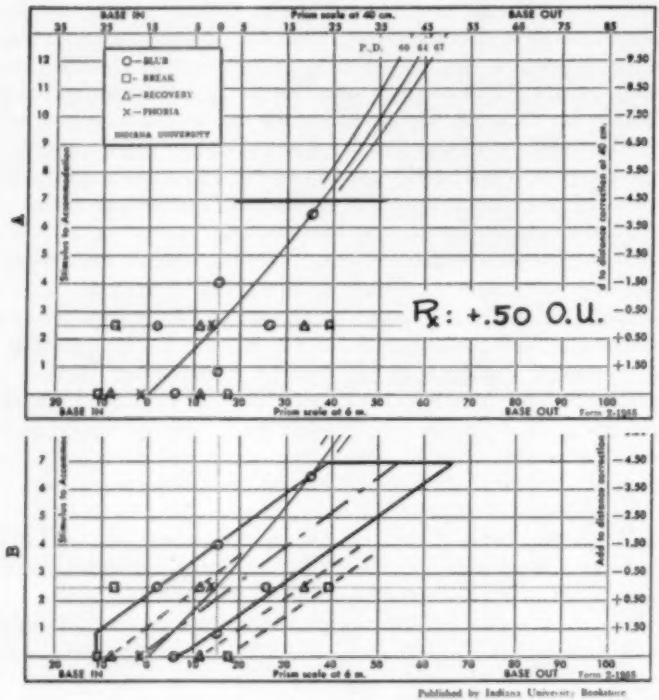

Fig. 2. (a) The graphically plotted examination data of Case 2. Note the similarity to Fig. 1a. (b) The zone of clear single binocular vision, determined by considering all the data. Note the dissimilarity to Fig. 1b.

likely to do. With already sizable fusional ranges existing, further increases of the amounts needed here are not likely to be achieved in an orthoptics program of reasonable length. Since there seems little justification for lenses to be worn at distance, reading lenses of +0.50 to +1.00 D. would appear to satisfy the patient's needs.

Case 3 (Figure 3) represents the type of data that occasionally emerges from a carefully done examination. The patient was a 30-year-old housewife who had not had a visual examination for ten years. Many tests were performed but the large quantity of data, when plotted, showed gross irregularities and inconsistencies. Prescribing on the basis of such data would be a hazardous undertaking. Such cases are best handled by a short orthoptics program consisting of general facility training. Saccadic and pursuit fixation exercises, jump ductions, accom-

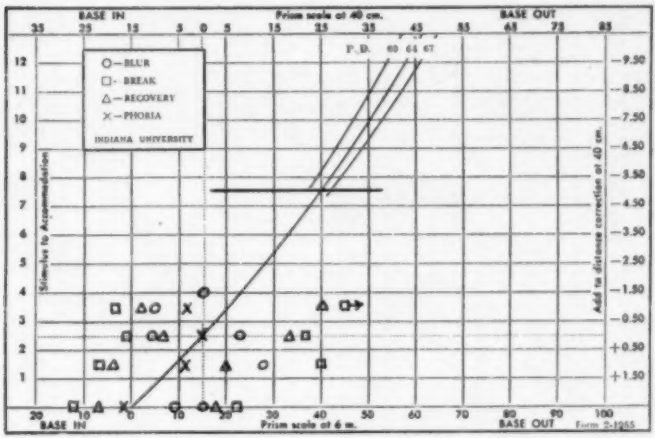

Fig. 3. Graphical representation of the examination findings of Case 3, showing a high degree of invalidity. Uncertainty as to which findings are the more valid or reliable prevents location of the zone boundaries.

modative rock, and third degree fusional training—virtually anything requiring carefully controlled use of the eyes—given in two or three office sessions, or carefully programmed for home training, will bring order out of the chaos and permit reliable data to be obtained on which to base the visual analysis. Hofstetter[8] has pointed out that oftentimes the visual training accomplished by the original examination routine itself is sufficient to accomplish this, and a second examination will reveal no evidence of the earlier unreliability. However, the therapeutic value of the short general orthoptics program is usually so pronounced in these cases, as evidenced by the patient's statements, that it certainly merits first consideration.

In Case 4 (Figure 4) the data appear reliable enough to outline the zone, determine the general nature of the problem, and indicate a method for its solution. Direct analysis would indicate the problem to be one of exophoria at all distances, with inadequate reserves to compensate for the excessive demand. Lenses with 5Δ base-in incorporated should relieve this problem. Noting, however, the low recoveries, the absence of ductional blurs and the probably excessive plus lens to blur at 40 cm., one should be suspicious of the quality of fusion. Such findings may be indicative of suppression and intermittent exotropia, particularly under conditions of stress or fatigue accompanying prolonged or intensive use of the eyes. While the prism lenses might relieve the fusional

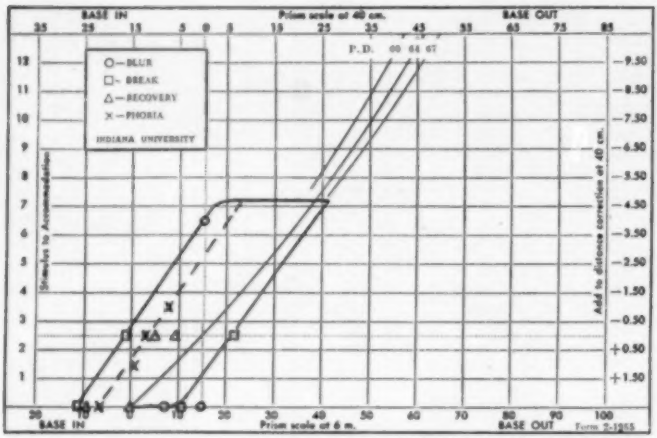

Fig. 4. A case showing apparent need for base-in prism, but also revealing a poor quality of fusion, as judged by the low recoveries, the excessive plus lens to blur at 40 cm., and the absence of blurs in the duction or vergence tests.

burden sufficiently to eliminate these problems, a much surer and more beneficial approach is to prescribe an orthoptics program to improve the quality of fusion. The prismatic correction may be given immediately or may be held back for later modification when the results of training can be evaluated. First, second, and third degree fusion exercises, moderate amplitudes of jump ductions, rotations and saccadic fixations with stereo targets through moderate amounts of base-in and base-out prism, can be performed in the office or at home. As a rule such programs need not and should not be lengthy ones. A maximum of six office sessions or three weeks of home training with weekly office calls for evaluation of progress should be sufficient in most cases to eliminate all traces of suppression, to widen the recovery range, to demonstrate facility in controlling accommodation and convergence, and, in short, to ensure the presence of the prerequisites for comfortable and efficient vision through the new spectacles.

Finally, Case 5 (Figure 5) is illustrative of a type of problem that seems to occur with great frequency among college students, judging from the number of such patients appearing in our clinic. As a rule the test findings show a high degree of reliability, in that re-examinations by the student clinician and by the clinic instructor produce essentially identical data. The characteristics of this syndrome are (1) complaints of blurring and fatigue while studying, (2) occasional reports of inter-

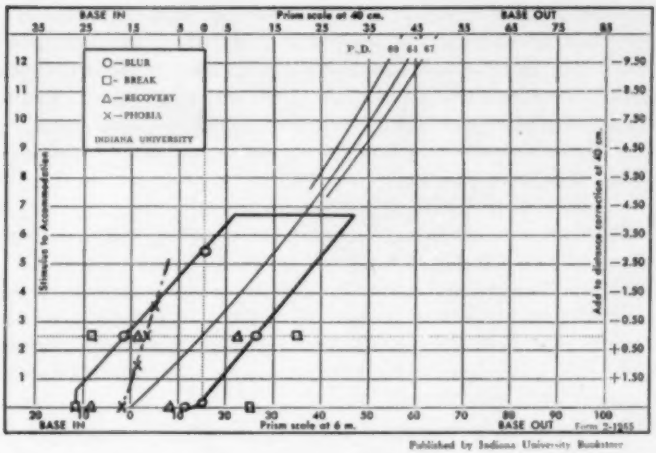

Fig. 5. A typical example of the examination data of a patient with poor facility of accommodation. Gross under-accommodation for near targets is revealed by the marked difference in slopes of the phoria line and the zone limits. The minus lens to blur at 40 cm. is often low and obviously invalid, though in the case shown here it was apparently adequate, agreeing with the base-in limits of the zone.

mittent diplopia while studying, (3) a short-duration distance blur following prolonged study, and (4) examination data which graphically show a marked difference in the slopes of the phoria line and the zone limits, the phoria line being more nearly vertical on the graph.

Since the data are so repeatable, a direct analysis of this type of case is often attempted. Superficially the problem appears to be one of high exophoria at near with inadequate base-out reserve. Reading lenses with reduced plus or increased minus would not be attempted because of the apparently low ACA ratio determined from the phorias. An orthoptic program of base-out training might be considered in the hope of increasing the near base-out reserve sufficiently to compensate for the phoria. But, with a zone of already sizable width it may be assumed that the physiological limit of positive fusional convergence is already being approached and that further increases would be small and difficult to achieve. The most practical solution might appear to be spectacles with a minimum of 4Δ base-in for near use only. A number of patients have received such lenses and typically have reported immediate relief of symptoms, but with a gradual return of the original difficulties after a few weeks.

A more basic source of the patient's difficulty is seen when we

evaluate the graph for validity of the findings. Clearly, some of the findings must be in error, for this kind of difference in slope between the phoria line and the zone limits is unrealistic in terms of the fundamental relationship between accommodation and convergence. It would for example indicate such absurdities as an inability above the 3.50 D. stimulus level to exert enough negative relative fusional convergence to reach the fusion-free position!

The most likely explanation of these anomalous data is simply that the patient failed to accommodate sufficiently during the phoria tests. The routine von Graefe technique for phoria testing contains two instructions: "Read the letters," and, "Report when the targets are vertically aligned." While complying with the second instruction, the patient may well forget the first and permit accommodation to relax, thereby demonstrating a higher exophoria because of the reduction in accommodative-convergence.

Even when precautions are taken which ought to assure adequate accommodation during the test, such as requiring the patient to read the smallest letters aloud while the targets are being aligned, it is not uncommon to find the same phenomenon. One cannot fail to be impressed by the seeming ability of some patients to read small letters while under-accommodating by as much as 1.50 D. or even more. It is conceivable that this is done by means of brief and minimal increases of accommodation, barely sufficient to bring the critical detail within the depth of focus, promptly followed by relaxation of accommodation back to a lower, more "comfortable" level. Little evidence of such purposeful oscillations of accommodation can be detected however, and we may continue to wonder if the depth of focus is really large enough to account for this phenomenon. Less exophoria may be found when using certain special techniques, such as the modified Thorington technique or the "flash" technique of occluding one eye in the von Graefe set-up and removing the cover for only brief flashes to localize the target, or by using the standard von Graefe method after first forcing accommodation to a higher level by adding —2.00 or —3.00 D. lenses and then reducing their power to the desired test level.

All of these observations point to an extreme reluctance on the patient's part to change accommodation. Accurate phoria testing requires accurate control of accommodation and assumes near equality of stimulus and response. This is less critical in duction tests, where accommodation is being forced to the limits of the depth of focus by way of the association of accommodation with the directly controlled convergence.

Therapy is simple in such cases, once the true nature of the difficulty is recognized. An orthoptics program aimed at improving the facility of accommodative response can be designed for home or office training. A variety of exercises involving accommodative rock or accurate focusing of a target whose distance is continuously changing will quickly develop the required facility and ease of accommodative control. Symptoms vanish, the phoria line on re-examination swings over into agreement with the other findings, and the apparent need for prismatic lenses at near is no longer present (see Figure 6). In the Indiana University clinic, patients have remained symptom free for as long as two years following such therapy. In most cases, their training programs did not exceed six half-hour sessions in the orthoptics clinic, or carefully prescribed daily home exercises over a two or three week period. A few patients have returned after one year with reports of onset of the original symptoms, though seldom as pronounced as formerly. Additional training has produced relief in these cases as readily as in the original programs.

SUMMARY

Graphic analysis embodies a framework of concepts regarding the functional relationship between accommodation and convergence which can be applied to orthoptics and visual training in many ways. Specifications of training procedures, made graphically, are convenient and easily

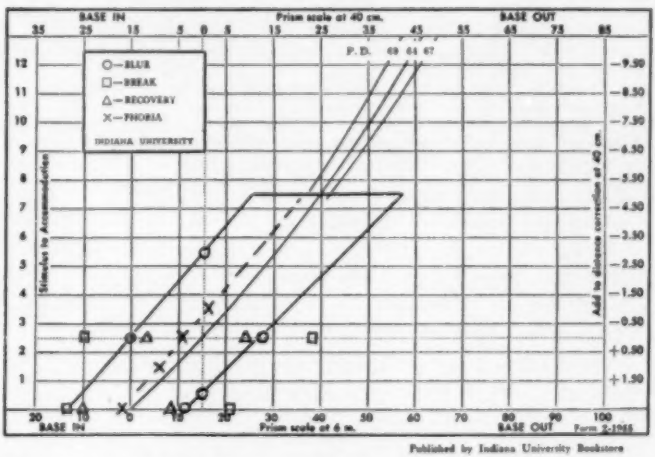

Fig. 6. The data of the same patient as Fig. 5, taken three weeks later, after six orthoptic periods of accommodative exercises. The slope of the phoria line now agrees with the zone limits.

applicable to a variety of instruments and techniques. Quantitative progress in the training of one or more visual functions is easily followed on the graph. In diagnosis of the basic visual problem, conventional direct analysis in terms of the ACA ratio, tonic convergence, and fusional convergence permits assessment of the deficiencies and evaluation of the relative efficiency of the methods available for providing relief—variations in lens power, prismatic additions, and/or visual training. The reliability and validity of the examination data can be estimated from the graph by internal checks involving known characteristics of the zone of binocular vision. Use of these known characteristics also permits inferential diagnosis of the visual problem in terms of malfunctions of the sensory, integrative, and motor processes of vision, or in terms of qualitative deficiencies in fusion or in facility of control of accommodation. This becomes especially useful when portions of the examination data are invalid or unreliable.

Five cases have been presented to illustrate application of this method of analysis in orthoptic programming.

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EMPIRICAL CORRECTIONS FOR ANISEIKONIA IN PRESCHOOL ANISOMETROPES*

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INTRODUCTION

It is generally agreed that maximum benefits from the correction of binocular vision anomalies are realized when begun before the child is six years old. However, this period is the most difficult one in which to obtain reliable subjective responses. Nevertheless, a great deal may be accomplished by careful objective tests and consideration of the optical correction. The two retinas should receive dioptric images as nearly equal as possible in resolution, size and shape as well as the objective correction of any motility obstacle. Further specific treatment may include training directed toward elimination of amblyopia and/or suppression.

The equalization of size and/or shape of the ocular images is often neglected. The empirical or estimated correction of aniseikonia in anisometropic children who do not respond to eikonometer testing is the subject of this paper.

A difference in size and/or shape of the *ocular* images may be a result of the ametropic correction (induced) or may be inherent in the visual mechanism. Usually it is a combination of both these factors. Distinction should be made between the *retinal* image and the *ocular* image. The former is the dioptric image formed on the sensory element layer of the retina, while the ocular image is that which reaches the highest cortical level, from each eye, just prior to fusion of the two. The ocular image is not necessarily the geometric equivalent of the retinal image, as modifications may be imposed upon it by the mosaic of retinal elements or by incongruency of the neural transmission or cortical representation.

In the correction of aniseikonia based upon eikonometer examination, the *ocular* images are equalized and the technique is wholly subjective. In empirical corrections only the *retinal* or *dioptric* images are considered and the prescription is based upon expected aniseikonia estimated from anisometropia. However, we have no way of knowing what, if any, effect is induced between the retina and the final cortical

*Read before the annual meeting of the American Academy of Optometry, Boston, Massachusetts, December 14, 1958. For publication in the July, 1959, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

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terminus of the image. Only eikonometer examination can give the total image disparity registered in the cortex.

Reliability of space eikonometer findings are dependent upon a sufficiently high level of maturation of the visual mechanism, acuity of at least 20/60 in the poorer eye, simultaneous binocular vision and good stereopsis. In addition the patient must have sufficient mental age and intelligence. Preschool children are often too low in level of visual maturation and in mental age to be considered good observers on the eikonometer; yet for them it is most important to eliminate all obstacles to fusion. Bannon[1] states that intelligence at least equivalent to that of a normal six-year-old child is required for reliable responses to space eikonometer testing. That aniseikonia is one of the obstacles to fusion and also an etiological factor in strabismus is widely accepted.[2, 3, 4, 5, 6, 7, 16]

NEED OF EMPIRICAL CORRECTION

Small astigmatic differences, of perhaps 0.75 D. or less, can usually be prescribed in full, without incorporating a size correction also, spherical equivalents could be prescribed if the reduction in vision is slight. Amounts greater than this may induce a significant degree of aniseikonia which, while not the only causative factor in amblyopia, may be an important etiological factor.

The idea of incorporating empirical size corrections with the refractive correction in anisometropes is not new. When reliable eikonometer measurements were not possible, a rule-of-thumb method was used in the Eye Clinic of the Dartmouth Eye Institute where aniseikonia as a clinical entity had its inception.*

Full correction of ametropia creates a better climate for prevention or reduction of amblyopia exanopsia than a partial correction, but it may then be necessary to include an aniseikonic correction along with the full ametropic correction, particularly where there is a large difference in the astigmatic error. The optimum goal is to prevent or eliminate suppression and amblyopia before school age. To accomplish this as rapidly as possible demands the use of all available measures.

In about one-third of the cases, the practitioner's estimate of the aniseikonia resulting from the anisometropia will be approximately correct; the aniseikonia resulting from astigmatic differences can usually be predicted more accurately than that due to spherical differences, or spherical differences in combination with a small astigmatic error of, say, 0.50 D. or less. When the difference in the spherical error is due

*The matter is also given consideration in a chapter on aniseikonia written by Robert E. Bannon, one of the early workers in aniseikonia at Dartmouth, for a forthcoming book by George Giles to be published in England.

to difference in axial length, there is no induced aniseikonia if the second principal planes of the corrective lenses are placed at the anterior principal foci of the respective eyes. This is another way of stating Knapp's law.[8] Conversely, when the difference in spherical error is due primarily to refractive ametropia (differences in relative curvatures of the refractive surfaces or of differences in indices of the media) aniseikonia is induced.

Since the practitioner does not have means at hand to measure the axial length of the living eye, although it can be done by Asuhton's X-Ray technique in the laboratory, there is no way of knowing whether the ametropia is of axial or dioptric origin. However, spherical ametropia is closely correlated with the axial length of the eye. Therefore patients with spherical anisometropia will usually have no aniseikonia, unless the corrective lenses are not located close enough to the anterior principal foci of the eyes.

The problem is complicated by the high proportion of patients who have a combination of axial differences and refractive differences together with a size disparity which the lens combinations may induce.

CLASSIFICATION

Types of aniseikonia may be classified according to the nature of the disparity as follows:

A. Normal: Due to asymmetric convergence, stereoscopic disparity due to separation of eyes (these are geometrical and present in everyone).

B. Abnormal: 1—Asymmetric, (a) pin cushion or barrel distortions (not correctible nor measurable at the present time), (b) ever increasing magnification in the direction of the apex of a prescribed prism (minimized by using certain base curves). 2—Symmetric, (a) overall (equal magnification in all meridians, comparable to a sphere), (b) meridional (greatest magnification in the meridian at right angles to the axis and zero in the axis meridian with varying amounts between, comparable to a cylinder), (c) compound (combination of overall and meridional comparable to a sphero-cylinder).

The following clinical evaluation of effect of aniseikonia is customary:

0 to 0.75%: not usually clinically significant.

1.00% to 3.00%: fusion and depth perception usually good, but likely to cause symptoms particularly in sensitive individuals.

3.25% to 5.00%: usually definite impairment of binocular vision.

5.00% and over: binocular vision usually very poor or entirely absent.

As in all tables of psycho-physiological values, these classifications are not mathematically exact, but there is a shading between the classifications. Although a high percentage of amblyopic patients have anisometropia with a concomitant aniseikonia of less than 3%, this amount could contribute to the suppression of the more ametropic eye.

Ogle[9, 10] reported 131 patients with spherical anisometropia, 30 per cent being axial in nature, 30 per cent refractive, and 40 per cent a combination of axial and refractive. That a high proportion of low and moderate myopia and hypermetropia with anisometropia are refractive or a combination of refractive and axial in nature is also supported by Tron[11, 12] and Paul.[13]

Fisher[14] concluded that the correlation between the amount of anisometropia and the measured size correction is low, but he also stated that of the group studied, all those with anisometropia greater than 2.62 D. had aniseikonia. Fisher did not differentiate between spherical and astigmatic errors. Hence, his conclusion as to the correlation may be questioned since some anisometropia could be axial, some refractive.

Later, Fisher[15] reported that every patient showing a difference of 0.50 D. or more in the cylinder power or a difference in axes of 15 or more degrees, may be expected to have aniseikonia. Gillott[16] concluded that 81 per cent of observers with an anisometropia of 1.00 D. or more had aniseikonia. Boeder[17] has also stated that the correlation between aniseikonia and anisometropia showed agreement with what was expected on the basis of the anisometropia in 50 per cent of the cases. However, he made no differentiation as to overall and meridional, or dioptric and axial.

The ophthalmometer should always be used in the examination of preschool anisometropes, since it will reveal any differences in corneal curves. These differences are often indicative of refractive ametropia, although there may be the compensating effects of indices and axial length.

In general, then, nearly all astigmatic differences induce aniseikonia: in spherical anisometropia nearly a third of the cases (Ogle) will have an aniseikonia accurately predictable from the anisometropia, and another 40 per cent of cases will have aniseikonia partly dependent on the spherical anisometropia. Another 30 per cent would have no overall aniseikonia at all in spite of the anisometropia.

In addition, there are cases[4, 17, 18, 19, 20, 21] of aniseikonia in which there is isometropia including bilateral emmetropia, and also cases in which the aniseikonia is different from, and sometimes even completely opposite to, that which would be expected from the anisometropia.

These situations are not predictable and are revealed only by eikonometer measurements.

The foregoing discussion points up the fact that there is no perfect substitute for a direct measurement of the aniseikonia in each patient. Nevertheless, where this is not possible, an empirical aniseikonic correction based upon all the available refractive data and the clinician's experience and judgment is usually better than none at all. This is particularly true for preschool children when it is desirable to prevent or eliminate suppression. There is no physiological adjustment to unequal images, although there is some "relearning" of spatial relationships when the eyes are corrected refractively but not aniseikonically.

PROCEDURES

The leaf room* as well as the tilting board can often give valuable information where the patient is not able to give satisfactory responses on the eikonometer. The writer has obtained correct responses to spatial distortion in a modified leaf room† ("snow room") induced by a meridional iseikonic lens with axis at 90 degrees before one eye on subjects under four years of age. He has been able to demonstrate the adequacy of a particular size correction by having a child report no distortion with an aniseikonic correction and then having him report the expected distortion by replacing the latter with a conventional full anisometropic correction without the size lens. Little or no distortion is observed in simple overall aniseikonia, nor is there usually distortion induced by overall lenses. Therefore, the leaf room can best be used in meridional testing.

Fit-over trial overall iseikonic lenses have diagnostic value if tried for spherical anisometropia and the effects on the child's symptoms noted. Several lenses may be made up in fit-over rings (for example a 1.50%, 2.50%, 3.50% and 4.50% overall) and tried for a short period.

If there is no suppression or deepening of existing suppression without incorporating a size correction, and no new or increase in old symptoms, it may well be that a size factor need not be incorporated in the spectacles.

It would appear that the best order of procedure to follow in treat-

*The leaf room is approximately a cube, open on one end, into which the observer can look and judge the relative positions of the walls, floor, ceiling and junction lines between these. The interior is lined with theatrical leaves to conceal the junction lines and corners and provide sufficient character to the flat surfaces. The leaves thus eliminate all but stereoscopic clues to distance judgment.

†Instead of lining his "room" with leaves, the writer used artificial pink canned snow sprayed fluffily on the surfaces to a depth of about ⅛ inch. This seems to be just as effective as leaves.

ing amblyopia or suppression in the preschool child would be:

1—Complete examination and refraction.

2—Test for anatomical integrity of macula (to attempt to determine if amblyopia therapy would be of benefit) using tests such as,

A—macula tester described by Goldschmidt[22] (by observation of Haidinger's Brushes).

B—Hall test.

C—Color vision test of each eye independently.

3—Prescription of full refractive correction and training and/or occlusion, partial or complete, periodic or constant.

4—After reduction of amblyopia, attempt made to get satisfactory results on eikonometer or leaf room.

5—Failing this (point 4), consideration given to incorporating an empirical aniseikonic correction in the spectacles and a recheck of the refraction.

An illustrative case may be cited. A boy, age 7, had 20/40 in the amblyopic and more ametropic eye with no lenses at first examination. After wearing the prescription of the full refractive correction in which there was 0.50 D. cylinder in one eye and 3.50 D. cylinder in the amblyopic eye its corrected acuity declined to 20/60. This deepening of the amblyopia may have been caused by the corrective lenses which gave clear but disparate optical images which the boy was unable to fuse. After wearing lenses which incorporated an empirical meridional size correction for two months the acuity was 20/30 in the amblyopic eye, 20/25 four months after this. Occlusion was not used. Several eikonometer examinations showed wide variance. Due to the low plus spheres, it did not seem likely that the initially reduced vision was due to unrelaxed accommodation.

Often, as in this case, visual training and/or occlusion can be bypassed and the amblyopia or suppression will be eliminated in a short time, sometimes in two to four weeks. However, if there is no improvement in a short time, visual training and/or occlusion should be instituted.

Many additional benefits may accrue from the use of an aniseikonic correction. For one, stereoscopic localization, one factor of depth perception is improved. Secondly, an upgrading of reading ability and school achievement is possible. That aniseikonic corrections, where needed, can result in an improvement in reading skill has been pointed out by Bannon,[23] Dearborn and Anderson.[24] Thirdly, there may be an alleviation of discomfort such as asthenopia, photophobia, and head-

ache.[25, 34] Also, as mentioned earlier, such a correction can also be used where suppression has not yet begun, but could be expected to appear due to the disparity in image sizes and/or shapes. Use of an iseikonic correction could well be the one element needed to prevent the development of suppression which might eventually become an intractable amblyopia exanopsia.

Where there is a motility problem that is to be attacked by visual training and there is a coexisting anisometropia and aniseikonia, the aniseikonia should certainly be corrected before the training begins,[7, 35] even if it is necessary to use an empirical correction. It is futile to break down a suppression and create clear binocular vision which is uncomfortable because of uncorrected aniseikonia; the patient will only resort to suppression again later to eliminate the discomfort.

AMOUNT OF EMPIRICAL CORRECTION

The amount of aniseikonia to be empirically corrected in each case will depend upon the clinician's judgment. At the Dartmouth Eye Institute, Bannon[26] frequently added approximately 1 per cent magnification for each diopter difference in ametropia, when reliable data could not be otherwise obtained. Ogle[27] has pointed out that 1½ per cent per diopter would be a closer approximation. As is often done in regard to the refractive elements of a prescription, it is prudent to undercorrect rather than overcorrect the aniseikonia.[28]

Further criteria that should be considered are the relative extent of interference with comfortable and/or efficient binocular single vision of the types of aniseikonic errors, i.e.: overall, meridional, or compound and the axis of the meridional type. More cases will need to be studied before sound clinical rules can be established on this point. At the present time, for those cases in which an empirical size correction is considered, the author feels it best to correct all significant meridional errors regardless of their axes. As has been pointed out, one cannot be so positive in regard to overall corrections.

Some examples* using the approximation of 1 per cent mag. per diopter follow:

(1) *Spherical* anisometropia, assume that the O.D. required +1.00 D. sphere and the O.S. required +4.00 D. sphere. The difference is 3.00 D.; hence 3% overall mag. might be incorporated in the prescription for the micreikonic (smaller image) right eye.

*In all these examples, only the estimated magnification due to refractive power is considered. "Shape" magnification due to the curvatures and thicknesses of the trial case or spectacle lenses is neglected.

(2) For an example of simple meridional aniseikonia, assume:

O.D.—2.50 D.C. x 180
O.S. Plano

The right lens might include magnification of 2.50% axis 180. The prescription ordered could be,

O.D.—2.50 D.C. x 180 ⌒ 2.50% x 180
O.S. Plano

The general rule to follow in determining to which eye to give the magnification is: the magnification goes to the more ametropic eye when the refraction is minus and conversely it is to be given to the less ametropic eye when the refraction is plus.

(3) An example of compound, with the rule, astigmatic anisometropia follows: The lens formula may be expressed in both minus cylinder and plus cylinder form to compare the size correction estimate for each. However, in ordering iseikonic corrections it is necessary to use the minus cylinder form.

O.D. +0.50 x 90
O.S. +1.25 ⌒ +3.50 x 90

(or)

O.D. +0.50 ⌒ —0.50 x 180
O.S. +4.75 ⌒ —3.50 x 180

Adding the size factor:

O.D. +0.50 x 90 ⌒ 1.25% O.A. ⌒ 3.00% x 90
O.S. +1.25 ⌒ +3.50 x 90

(or)

O.D. +0.50 ⌒ —0.50 x 180 ⌒ 4.25% O.A.
O.S. +4.75 ⌒ —3.50 x 180 ⌒ 3.00% x 180

Actually the size correction would be the same from the standpoint of equalization of the size and shape of the two retinal images. The practitioner need not be concerned with this (unless he makes his own translations) as the translator will decide how the magnification effects are to be divided between the two lenses on the basis of the best lens designs.

Any difference in relative sizes of two fused cortical images as a result of two choices of transposition of the iseikonic elements, would have little, if any, clinical significance. In correcting aniseikonia, one is concerned only with equalization of the images from the two eyes—making them the same relative size and shape—and not with whether the completed fused cortical image is larger or smaller or of different shape than it was when uncorrected or when corrected by a different

iseikonic transposition. Pragmatically, the overall component might be eliminated in ordering the prescription of the last example, since the aniseikonia is only estimated and has not been actually measured.

The relationships between the dioptric figures and the iseikonic figures may be more readily visualized by placing the values on optical crosses for each eye, being careful to assign the estimated iseikonic values to the proper arm of the proper cross in accordance with the rule given earlier for showing which eye (or the meridian of which eye) requires the magnification.

Before continuing with more complex examples, the concept of the aniseikonic ellipse and the rule for transposition of aniseikonic prescriptions will be discussed briefly. The image in the more astigmatic eye will be the more elliptical of the two. We are referring to optical effects only and disregarding any neurological disparities. The minor diameter of the ellipse will correspond to the meridian requiring magnification. The axis of the meridional magnifier will therefore need to be parallel to the major diameter. If the astigmatic errors are equal in amount, but different in the orientation of their principal meridians, the ratio of the major to the minor diameters will be the same for each eye's ellipse but their long axes will not be parallel. That ellipse known as the aniseikonic ellipse is a binocular ellipse which is the field representation of the differences in magnification of the two monocular ellipses in every meridian. It could be thought of as the composite ellipse of the cyclopean eye which would require iseikonic lenses to correct its form to a true ellipse or true circle.

The orientation of monocular ellipse and the axis of a correcting meridional iseikonic lens are not to be confused with the declination or delta error which is one of the test parameters of the space eikonometer. The axis of the correcting meridional iseikonic lens is a derivation of the three test parameters, axis 90°, axis 180° and delta, arrived at by employing analytical geometry. Since the delta error is determined by measuring and this discussion is concerned only with estimating, the delta error will be neglected except to point out that it is not the same as the meridional axis.

The mechanics of transposition of iseikonic formulas are the same as for spheres and cylinders except that in the latter only one lens is involved, while in the former the lenses for both eyes are involved. The transposition convention is to give values with a plus sign to the right lens and values with a minus sign to the left. For example O.D. 3.00% x 180 transposes to +3.00% O.A. ⊃ —3.00% x 90 which becomes: O.D. 3.00% O.A., O.S. 3.00% x 90.

While both forms (pretransposition and postransposition) are equivalent from the standpoint of correcting the aniseikonic ellipse, the postransposition corrected ellipse will be flatter horizontally than the pretransposition corrected ellipse. The study of shape constancies is well developed in Bartley's recently published book on perception.[29]

(4) As an example of mixed astigmatism, assume this pair of lenses:

O.D. +2.00 ⊂ —4.00 x 180
O.S. Plano

The estimated aniseikonic correction would be, using the minus cylinder form:

O.D. +2.00 ⊂ —4.00 x 180 ⊂ 4% x 180
O.S. Plano ⊂ 2% O.A.

Using the plus cylinder transposition:

O.D. —2.00 ⊂ +4.00 x 90 ⊂ 2% O.A.
O.S. Plano ⊂ 4% x 90

Here, again, the clinician's judgment will be required to determine propriety of prescribing the overall component.

(5) When the cylinder axes are different, but supplementary, the estimation of the size correction is slightly more confusing. It is simplest to transpose the lens formula into minus cylinders so that the axes of the cylinder and meridional magnifier are the same to avoid confusion. For example:

O.D. +2.00 ⊂ —4.00 x 135 ⊂ 5% x 135
O.S. +1.00 ⊂ —1.00 x 45 ⊂ 1% O.A.

The meridional component is 5% because the effective algebraic difference in the cylinders is 5.00 D. since their axes are at right angles to each other.

(6) More complex is the situation in which the astigmatic axes are not parallel nor supplementary. Example:

O.D. —4.00 x 30 ⊂ 4% x 30
O.S. —1.00 x 90 ⊂ 1% x 90

In order to reduce this to its simplest form, that of one meridional and one overall lens, it is necessary to resort to trigonometry, although it could be done graphically. The approximate equivalent would be O.D. 4.5% x 25; O.S. 0.75% O.A. which could be determined by use of formulas for combining obliquely crossed cylinders or by appropriate tables. However, it should be emphasized that such exactness is hardly justifiable in view of the liberties taken in estimating the aniseikonia. Practically, the 0.75% O.A. of the O.S. may be eliminated, making it necessary to specify only the meridional correction. To simplify the

work, when the two types of axes are close they should, when it is felt possible, as in this case, be altered to make them parallel. In the case at hand, the magnification axis would be changed to 30° to conform to the refractive axis. Moving the cylinder axis 5° in a 4.00 D. cylinder would cause a blur not likely to be tolerated by the patient, while shifting the mag. axis would have no adverse effect.

TRANSLATION AND DISPENSING

Many of the overall corrections can be fabricated in local laboratories from stock blanks, with the clinician making his own translation by the method of his choice such as that described by Bechtold[30] or the new simplified procedure outlined by Haynes.[31] Meridional formulas requiring bitoric lenses must be fabricated in the Southbridge plant of American Optical Company.

Rules for approximate magnification changes may be summarized as follows:[31a]

1. "Every diopter change in front surface power changes the per cent magnification by one-fifteenth of the center thickness in millimeters."
2. "Every millimeter change in center thickness changes the per cent magnification by one-fifteenth of the front surface power in diopters."
3. "Every millimeter change in position before the eye changes the per cent magnification by one-tenth of the effective power. Movement away from the eye for plus lenses increases the magnification; movement toward the eye for plus lenses decreases the magnification. The opposite is true for minus lenses."

The procedure outlined in this paper for correcting anisometropically induced aniseikonia may be employed by any optometrist as long as the principles as well as the limitations are understood. However, special training in aniseikonia and eikonometry would definitely be an advantage for the practitioner, not only for accuracy and understanding in empirical procedures, but also for its value in giving a superior over-all concept of refraction in general.

The practice of simply ordering steeper or shallower base curves for anisometropic corrections is subject to occasional error, as it is possible to actually add to the size difference by increasing the flexure of certain powered *minus* lenses which increases the sagitta and thus the vertex distance of the lens. This possibility has been pointed out by Bannon and Ogle[32] among others. The clinician may prefer to order empirical aniseikonic prescriptions in terms of per cent magnification

desired rather than to attempt to make a translation into curves, thicknesses or bevel specifications unless he is familiar with one of the methods of translation. In either case, it is the clinician's prerogative and responsibility to specify to the optical laboratory the prescription desired. It is of no concern to the laboratory whether the prescription is based on actual measurements or empirical estimation. The laboratory should not be put into the position of prescribing by being requested to make the estimations based upon anisometropia, or other factors: this is the sole responsibility of the practitioner.

Precedents for prescribing ophthalmic corrections based on empirical estimations are numerous as, for example, in the amount of prism prescribed for heterophorias compared to the deviation measured; in the estimated correction necessary for vertical prismatic imbalances in anisometropic multifocal cases; and, in fact, in the estimation of the time it is desirable to have a re-examination.

The necessity of incorporating a bicentric (slab-off) lens in some of the examples given, has not been considered since, in children's glasses, the vertical diameter of the lens is usually small, and it is not so necessary that the visual axes be depressed below the optical centers as in multifocal corrections.

In dispensing the completed iseikonic spectacles to children, the usual rules[33] should be followed, such as fitting the lenses as close to the eyes as possible when the aniseikonia agrees with the anisometropia (as it should in empirical corrections),* using small lens sizes, and avoiding extreme shapes. All of these factors can be followed easily in children's spectacles as they are, of course, small and shapes are usually not so extreme. Another important point is to avoid rocking pad frames, since the distance of the eyewire from the vertex of the cornea will not remain fixed as the pad arms become bent. This will place the lenses closer to or farther from the eyes than the desired eyewire distance.

SUMMARY

The importance of empirically estimated aniseikonic corrections in anisometropic children who are too young or retarded to yield reliable eikonometer findings is discussed. Some of the pertinent literature supporting the basis of the described procedure is reviewed and certain limitations are emphasized.

Examples are given to show the nature and approximate amounts of aniseikonia expected in selected cases of anisometropia. Transposition,

*The opposite holds true when the aniseikonia measured does not agree with what would be expected on the basis of the anisometropia, i.e., the lenses are fitted as far from the eyes as practical.

translation and dispensing procedures are also briefly discussed.

In the absence of more accurate subjective data, the prescribing of *empirical* corrections for estimated aniseikonia may greatly enhance the optimum development of binocular vision in young children who would otherwise be deprived of the benefit of this possibility.

The writer wishes to express his appreciation to Dr. Robert E. Bannon for the generous use of his time in reading the original manuscript and making many valuable criticisms and suggestions which were incorporated.

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THE USE OF DRUGS IN REFRACTION. Second Edition. D. W. A. Mitchell. Published by the British Optical Association, 65 Brook Street, London, W. 1, England. 146 pages. Illustrated. Cloth. $4.70 postage prepaid. 1959.

Optometrists in England do not use drugs in therapeutic work but do use them on occasion as cycloplegics in their refractive work. This book deals with this limited subject. The author, who is the late senior staff refractionist of the London Refraction Hospital and a member of the Pharmaceutical Society, has prepared this text to provide optometrists with material of practical and clinical interest in the use of drugs, together with material of theoretical nature to enable them to understand the various problems involved.

The second edition is concerned with the drugs used as cycloplegics, their preparation and methods of administration. It also reviews ocular examinations made under cycloplegia. Here the author discusses not only how the drug is used, presenting its detailed effects, but also presents case reports dealing with the indications and contra-indications for use with various types of patients.

RUDOLPH EHRENBERG, O.D.

THE RELATIONSHIP BETWEEN ANGLE LAMBDA AND THE RESIDUAL ASTIGMATISM OF THE EYE*

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INTRODUCTION

It is common clinical knowledge that the astigmatism of the eye as measured by routine clinical techniques, both subjective and objective, differs in a limited and somewhat predictable amount from the astigmatism attributable to the toric curvature of the cornea as measured by means of an ophthalmometer. Even when the ophthalmometrically determined astigmatism is computed for optical effectivity in the conventional refracting or spectacle plane, there typically is found a difference which in clinical discussions is referred to by various names such as "physiological' astigmatism, "residual" astigmatism or "lenticular" astigmatism.[1a] Several attempts have been made and rules of thumb formulated to allow for this difference in the clinical attempts to compare ophthalmometrically measured values with the total astigmatism as measured by subjective and objective techniques. Examples of such formulations are Javal's rule, Neumueller's tables, and modifications of Neumueller's system by Fry and Mote.[1b] For the most part these clinical rules assume a relatively constant value of about 0.50 and 0.75 diopters of astigmatism as the allowance to be made in the comparison of the total and the ophthalmometrically determined astigmatism.

That a difference typically occurs between the total astigmatism and the ophthalmometric astigmatism was early noted by Donders.[2a] He attributed it to the crystalline lens. Subsequently Tscherning[3a] recognized that other factors could be responsible. Duke-Elder[4] gives the astigmatism due to an angle of five degrees between what he called the pupillary line and the optic axis as 0.1 diopter, citing Gullstrand.

It has been recognized since the middle 1800's that the eye when it is regarded as a centered optical system typically is not directed precisely at the object of fixation but that the eye is optically turned out or in as the case may be. The reason usually given for this obliquity

*Read before the annual meeting of the American Academy of Optometry, Boston, Massachusetts, December 15, 1958. For publication in the July, 1959, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

This report was submitted in partial fulfillment of the requirements for the Master of Science degree in Physiological Optics, Indiana University, June, 1956.

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has been the slight temporal displacement of the fovea with respect to the posterior pole of the eye. The knowledge of this obliquity coupled with the fact that astigmatism can be induced by the obliquity of incidence of the chief ray has led to the relatively popular generalization that this is one of the significant causes of the above described difference. The obliquity has been measured in the laboratory many times. One such study was Donders'[2b] measurement of the angle between the "axis of the cornea" and the "visual line" which gave an average of 5.082 degrees for 15 emmetropic eyes. This angle is based upon a perpendicular through the center of the horizontal chord of the cornea and the "visual line" which is a line from the point of fixation to the center of the entrance pupil. Another investigation of the obliquity was Tscherning's angle alpha, the angle between the "optic axis" and the "visual line." In this case the optic axis was determined by attempting to line up the three reflections of a small light from the anterior surface of the cornea and the anterior and posterior lens surfaces. He found that angle alpha varied from 4.0 to 7.0 degrees.[3b] Laurance[5a] gives the average size of angle alpha, the angle between the "optic axis" and "visual axis," as 5.0 degrees. He used an arbitrary method of calculation, based on the displacement of the fovea 1.25 millimeters from the posterior pole and a distance of 15 millimeters from the nodal point to the fovea. Thus it can be seen that the literature gives the impression that the obliquity of the visual apparatus is about five degrees.

Gullstrand was among the first to advocate the use of the pupillary axis as the reference line in place of the optic axis since the optic axis does not normally exist as a single straight line and hence cannot be determined except by empirical approximation. As a result he formulated an angle which was the same as angle lambda and he recommended that it be used to describe the obliquity of the eye. The importance of using the readily determined line of sight was first pointed out by Blix.[6]

A problem arises when an attempt is made to substantiate the role which obliquity of the eye plays in creating the difference between the total astigmatism and the ophthalmometrically determined astigmatism. As far as can be determined a statistical analysis of these variables has not been done before. In an effort to determine the statistical relationship between certain of the variables the present study was undertaken.

STATEMENT OF THE PROBLEM

The purpose of this study was to measure the statistical correlation, r, between angle lambda and the residual astigmatism in a group of subjects. Angle lambda is defined by Fry[7] as the angle between the pupillary axis and the line of sight. The pupillary axis is defined as

the line perpendicular to the cornea through the center of the entrance pupil. The line of sight is defined as the line connecting the center of the entrance pupil to the point of fixation, where the point of fixation is presumed to be the object point in the field of view corresponding to the fovea. The eye normally uses the fovea for direct fixation. It is obvious from the above definitions that the vertex of angle lambda is at the center of the entrance pupil.

Residual astigmatism[8] as used here is the difference between total astigmatism and corneal astigmatism: the total astigmatism is that determined to exist in the spectacle plane by a subjective refracting technique, and corneal astigmatism that determined with the ophthalmometer and computed in terms of its effectivity in the spectacle plane. Thus the residual astigmatism will include all of the astigmatism not directly attributable to the toric curvature of the cornea, and may be presumed to include astigmatism attributable to the obliquity of the line of sight at the cornea, and to astigmatism inherent in the optics of the eye exclusive of that determined in the ophthalmometer reading.

Incidental to the principal investigation as stated above the following information was also determined: the correlation between angle lambda and the spherical equivalent refractive error of the eye; the apparent horizontal decentration of the pupils with respect to the limbal borders of the iris; and the reliability of the various measurements taken.

INSTRUMENTATION AND PROCEDURE

The 55 subjects for the determination of angle lambda consisted of 51 students and four members of the faculty of the Indiana University Division of Optometry. The average for the group was 25.5 years and the range was from 20 to 56. All of the subjects had normal central acuity in both eyes when corrected. None of the subjects wore spectacles during the experiment, but all subjects were able to see the fixation target with ease and without any indication of unsteady or lost fixation.

In correlating angle lambda and the residual astigmatism only 44 of the total group were available for both tests. The average age for these was 23.7, the range from 20 to 41.

For determining angle lambda an instrument along the lines of Tscherning's Ophthalmophakometer[8c] was constructed (Figure 1). A telescope focused for one meter was mounted at the center of a 7¼-inch circular fluorescent light (G-E std. cool white). The eyepiece of the telescope had a graduated horizontal reticle scale in which the pupil, or the corneal reflex, or the apparent midpoint between the corneal limbal borders could be centered, or on which the eccentricity could be determined. A meter stick with a small movable glider fixation target was

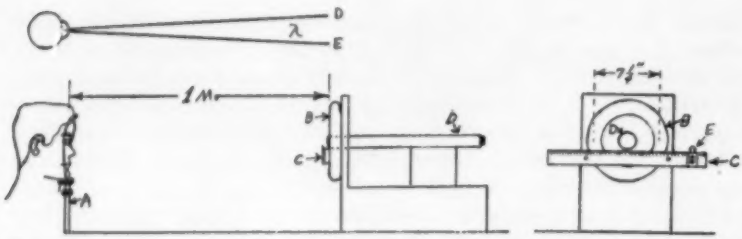

Fig. 1. Left. Side view. Right. Subject's view. Schema for method of measuring angle lambda and pupil eccentricity. A. head and chin rest. B. circular fluorescent light. C. meter stick scale. D. telescope. E. movable fixation target. λ, angle lambda.

mounted at right angles and just below the telescope. The arrangement was such that the objective lens of the telescope, the fixation target, and the surface of the light were very nearly in the same plane, perpendicular to the axis of the telescope. An adjustable head-and-chin rest was mounted so as to permit the placement of the corneal apex of the subject's eye one meter from the objective lens of the telescope. The illumination provided by the fluorescent lamp and the supplementary lighting in the room was 85 foot candles at the subject's eye. The movable fixation target consisted of a very fine black cross on a piece of white translucent plastic attached to a movable glider on the scale. The path of the center of the cross was 6 millimeters below the center of the objective lens, so as not to occlude the view through the telescope when in the zero position.

To measure angle lambda the subject was seated comfortably with his head in the head-and-chin rest and was directed to fixate the center of the telescope objective. The position of the corneal reflex of the fluorescent light in the pupil was noted as a preliminary observation of the orientation of angle lambda. Next the subject was directed to fixate the movable target which was adjusted along the meter scale until the circle of light was seen by the observer to lie at the center of the apparent pupil. The distance of the target from the center of the telescope was then recorded. This procedure was repeated two more times with the fixation target starting from alternate ends of the scale. The average of these three readings over 1 meter was taken as the tangent of angle lambda.

The entire procedure described above was then repeated for the other eye. All 55 subjects (110 eyes) were used in this part of the experiment.

For 30 of the subjects (60 eyes) the findings were repeated at a separate sitting, to ascertain the reliability.

To determine the apparent horizontal decentration of the pupil with respect to the limbal borders of the iris the nasal and temporal borders of the iris and the nasal and temporal borders of the pupil were determined on the reticle scale in the eyepiece, and recorded.

Corneal astigmatism was measured on the 44 subjects with an American Optical Company Micromatic ophthalmometer.[9] To determine the reliability of the ophthalmometer findings the measurements were repeated on 24 of the subjects (48 eyes).

Because some of the previous investigations of corneal astigmatism were made on a Bausch and Lomb keratometer,[10] such as the study by Mote,[11] another group of 24 subjects (48 eyes), roughly the same 24 used in the reliability study, were also examined with the Bausch and Lomb keratometer to observe the correlation obtained between the two makes of instruments.

The manufacturers' instructions[9, 10] were followed precisely for both instruments.

Total astigmatism was determined by means of an objective technique, retinoscopy, followed by a fogging subjective technique. Both of these techniques were essentially the same as those described by Borish[1c] and may be described briefly as follows. Plus 1.00 diopter was added to the sphere of the refractive error as determined by retinoscopy, or more if required to assure that both principal meridians were focused in front of the retina. A "T" dial was rotated so that the stem of the "T" coincided with the cylinder axis as determined by the retinoscope. The axis determination was refined by rotating the "T" alternately clockwise and counter-clockwise until the "point of greatest contrast" was found. Minus cylinder was then added in 0.25 diopter increments with its axis coinciding with the most blurred component of the "T" dial. The subjective cylinder was taken as that amount which made the components (stem and crossbar) of the "T" dial equally clear, or the last lens before a reversal occurred if equalization was not possible. The sphere power was obtained by means of the bichrome test taking the most plus or least minus sphere value for which Verhoeff[1d] circles appeared equally black in the red and green fields. If equalization did not occur then the most plus or least minus sphere that caused the Verhoeff circles in the green field to appear blacker than the circles in the red was recorded. If difficulty was experienced with the bichrome test then the standard "most plus or least minus giving the best visual acuity" technique was employed to determine the sphere. This occurred only twice with this group. Every effort was made to use the same criterion for determining the cylinder and sphere for the 44 subjects. The cylin-

drical portion of this subjective finding was taken as the total astigmatism of the eye at the spectacle plane.

The residual astigmatism was determined by taking the difference between the total astigmatism and the corneal astigmatism as follows: The effective corneal astigmatism at a spectacle plane distance of 13.75 millimeters from the cornea was computed taking into consideration the sphere of the subjective finding, in the manner described by Neumueller.[10] Then using the formula, $C_v = (\mathrm{Sin}^2\theta)$ (cyl), the vertical component, C_v, of the effective corneal astigmatism was determined and with, $C_h = (\mathrm{Cos}^2\theta)$ (cyl), the horizontal component, C_h, was determined. The same formulas were used to determine T_v, the vertical component of the total astigmatism, and T_h, the horizontal component of the total astigmatism. In these formulas "θ" is the angle between the axis of the correcting cylinder and the horizontal meridian, and "cyl" is the dioptric power of the correcting cylinder in the case of the total astigmatism, and the computed cylinder at the spectacle plane in the case of corneal astigmatism. Residual astigmatism, R, is obtained with the formula, $R = (T_v - T_h) - (C_v - C_h)$. A plus value for R indicates that the residual astigmatism has the most converging power in the horizontal meridian and a negative value indicates that the most converging power is in the vertical meridian.

RESULTS

The results of the statistical analysis are summarized in Table 1. Figures 2-7 give a pictorial account of these findings.

TABLE 1.

SUMMARY OF THE STATISTICAL ANALYSIS OF THE CORRELATION OF ANGLE LAMBDA WITH RESIDUAL ASTIGMATISM CORRELATIONS

Angle Lambda with Residual Astigmatism

(44 right eyes) $r = -0.15$* (44 left eyes) $r = -0.27$*

Angle Lambda with Refractive Error

(44 right eyes) $r = +0.15$* (44 left eyes) $r = +0.14$*

	Right Eyes		Left Eyes	
	Mean	Standard deviation	Mean	Standard deviation
Angle lambda (N = 55)	+1.1	1.6	+1.6	1.6
Residual astigmatism (N = 44)	+0.57 dio.	0.54	+0.59	0.41
Decentration of the pupil (N = 44)	0.3mm nasal	0.15	0.3mm nasal	0.13
Refractive error (N = 44)	—0.73 dio.	1.4	—0.80 dio.	1.4

*These correlations do not differ significantly from zero at the 5 per cent level of confidence.

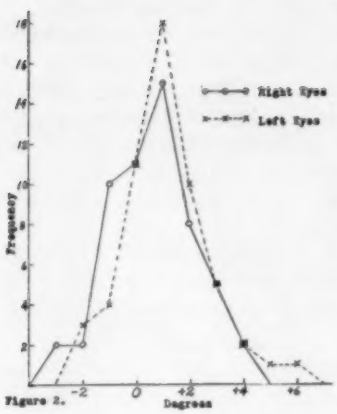

Figure 2.

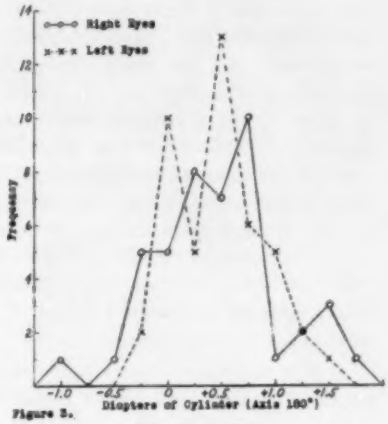

Figure 3.

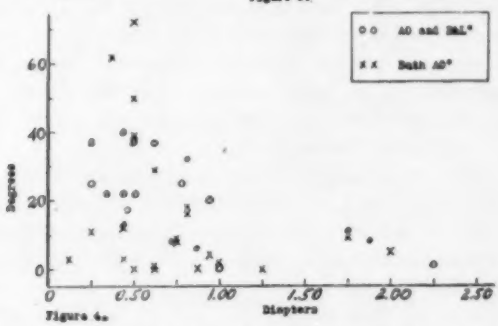

Figure 4.

Fig. 2. Upper left. Frequency distribution for angle lambda.
Fig. 3. Upper right. Frequency distribution for residual astigmatism.
Fig. 4. Lower. Scattergram relating repeatability of axis determinations to ophthalmometric astigmatism. *These represent 22 eyes measured twice on different instruments (AO and BŒL), and 22 eyes measured twice on the same (AO) instrument. The average ophthalmometric astigmatism for each pair of findings is reported on the abscissa and the acute angle between each pair of axis determinations reported on the ordinate.

Angle lambda for the total sample of 55 subjects has a mean of +1.1 degrees with a standard deviation of 1.6 for the right eyes, and a mean of +1.6 degrees with a standard deviation of 1.6 for the left eyes. A plus value for angle lambda indicates that the line of sight is nasal with respect to the pupillary axis (Figure 2). The reliability coefficient for angle lambda for the sample of 30 (60 eyes) is $r = +0.89$ with a standard error of measurement, $\sigma_e = \pm 0.46$ degree.

The residual astigmatism for the sample of 44 subjects has a mean of +0.57 diopter with a standard deviation of 0.54 for the

right eyes, and a mean of +0.59 diopter with a standard deviation of 0.41 for the left eyes. In both cases, right and left eyes, the mean residual astigmatism has the most converging power (when referred to the refracting power of the eye) in the horizontal meridian. When expressed in terms of the correcting lens it would be "minus cylinder axis 90 degrees" (Figure 3). The reliability coefficient for a sample of 24 eyes for the corneal astigmatism as measured directly with the American Optical Company ophthalmometer is $r = +0.74$ with a standard error of measurement, $\sigma_e = \pm 0.25$ diopter.

The reliability coefficient resulting from measurements taken once with the AO Company ophthalmometer and again with the B&L keratometer on 24 eyes is $r = +0.87$ with a standard error of measurement, $\sigma_e = \pm 0.21$ diopter.

The ophthalmometer axis measurements do not permit a comparable analysis. Due to the cyclic feature of the axis notation system it is not appropriate to correlate these findings by conventional techniques. Figure 4 gives some indication of the reliability of these measurements. It is apparent that for the lower amounts of corneal astigmatism the axis measurements are quite variable. For the higher amounts of astigmatism, on the other hand, the average observation error would appear to be well under five degrees.

The correlation of angle lambda with residual astigmatism for a sample of 44 subjects is $r = -0.15$ for the 44 right eyes, and $r = -0.27$ for the 44 left eyes (Figure 5). The conventional techniques for testing the significance of correlation coefficients such as the standard error of "r" with the normal probability table, the "t" test, and the "F" test all indicate that at the 5% level of confidence the obtained "r's" do not differ significantly from zero. Fisher's[12a] "r" to "z" transformation shows the 5% confidence interval for the "r" of the right eyes to range from —0.36 to +0.06 and that for the left eyes to range from —0.07 to —0.48. This technique avoids the errors introduced in cases of very high or very low correlations when testing for significance by the conventional methods. The ranges found with Fisher's method are essentially in agreement with the conventional methods in this case.

The fact that the correlations are minus rather than plus may in itself be regarded as a type of result contraindicating the likihood of a simple cause-effect relationship between the obliquity, angle lambda, and residual astigmatism.

Figure 6 is a scattergram showing the raw ophthalmometer findings plotted against the total astigmatism. Only the cases in which the axis

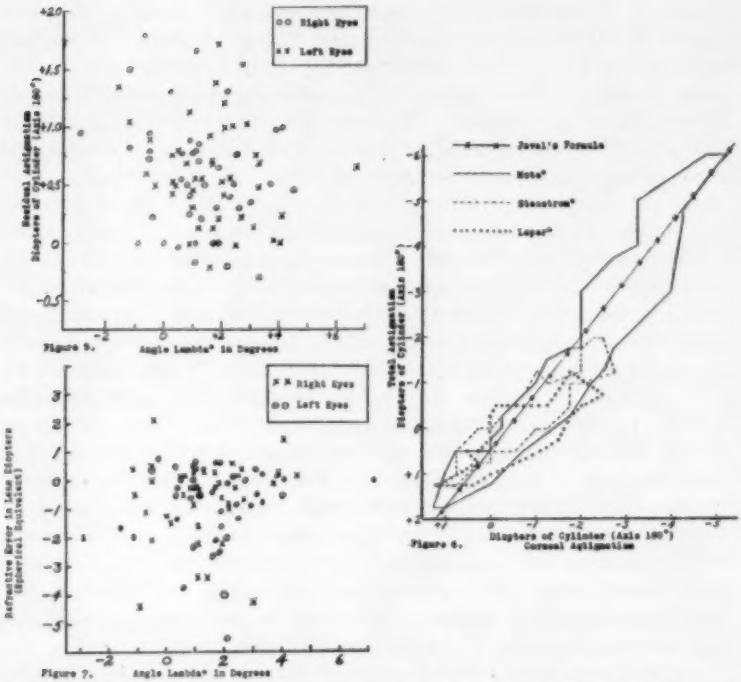

Fig. 5. Upper left. Scattergram for relationship between angle lambda and residual astigmatism. *Plus values for angle lambda represent the line of sight nasal to the pupillary axis.
Fig. 6. Right. A comparison of the data of Mote, Stenstrom and Loper. *Only the enclosing outlines of the scattergrams are shown.
Fig. 7. Lower left. Scattergram for relationship between angle lambda and refractive error. *Plus values for angle lambda represent the line of sight nasal to the pupillary axis.

fell within 30 degrees of the horizontal or vertical were included. It can be seen that the data of this sample are in essential agreement with those of Mote[11] and Stenstrom[13] for the size of the sample. Their data include more cases in the higher ranges of total astigmatism, and in the higher ranges of corneal astigmatism axis 180 degrees.

The mean decentration of the pupil for the sample of 44 subjects was found to be 0.3 millimeters nasally with a standard deviation of 0.15 in the 44 right eyes, and 0.3 millimeters nasally with a standard deviation of 0.13 in the 44 left eyes.

Figure 7 is a scattergram showing the correlation, r, between

angle lambda and the spherical equivalent refractive error for the same sample of 44 subjects used in the study of angle lambda and residual astigmatism. For the 44 right eyes $r = +0.15$ and for the 44 left eyes $r = +0.14$, values which do not differ significantly from zero at the 5% level of confidence. The mean refractive error of the right eyes is —0.73 with a standard deviation of 1.4 and —0.80 for the left eyes with a standard deviation of 1.4.

DISCUSSION

Angle lambda derives its practical importance from the fact that it is easily determined clinically, whereas the other angles closely related to it are not. As noted above it is frequently cited as one of the contributing factors in the total astigmatism of the eye. The finding of values for angle lambda of +1.1 degrees for the right eyes and +1.6 degrees for the left eyes can be shown by the "t" test[12b] to be significantly different at the 0.1% level of confidence from the five degrees classically quoted. It is recognized by the writer that the other angles, cited above in the introduction, were measured by different methods, though it is not clear from the present study that this accounts for the difference. The findings in this sample would appear to be more nearly in agreement with those of Christakos[14] which were obtained in a somewhat similar manner, but nevertheless not by a technique which permits direct comparison. The view has been expressed[5b] that these various angles representing the obliquity of the eye are practically the same and that the same representative value can be applied to all.

When considering the obliquity of the eye there are two possible concepts of variability that must be differentiated in analyzing the angles. First, there is a variability within angle lambda itself which is demonstrated in this case to be approximately normally distributed. Accordingly an arbitrary value, say one of the means found in this study, cannot be applied precisely to an individual case. Second, the variously named angles of the eye are not identical, either in definition or in technique of measurement. These angles have been given values all the way from +1.5 to +7 degrees. Here there is even less justification in applying the value obtained for any one of the several angles to represent the obliquity in an individual case. In any event, if a single representative value is required, or desired, to express the obliquity of the typical eye some consideration should be given to adopting a value lower than five degrees.

Residual astigmatism of +0.57 diopter for the right eyes and +0.59 diopter for the left eyes in this sample does not appear to be significantly different from that found in many other studies.

It is of incidental interest to note that in the clinical literature there has been some discussion about a variation of residual astigmatism with age. Due to the limited age range represented here it is not possible to confirm or refute this. Neumueller[16] gives a value of 0.25 diopter "against the rule" for ages below 30. The average age for this group is 23.7 years as given above.

An inspection of the scattergram, Figure 5, and the statistical summary, Table 1, shows no linear statistical relationship between angle lambda and the residual astigmatism of the eye. Thus, it can be said that in this case if the obliquity of the eye does contribute to the residual astigmatism it does so in a manner not detected by the conventional statistical technique employed here. There is no significant difference at the 5% level of confidence between the correlations found for the right and left eyes, suggesting that the two samples are from the same statistical population.

Incidental to this study it was found that the average apparent pupil is decentered nasally 0.3 millimeters with reference to the geometric center of the cornea as outlined by the limbal borders of the iris. The limited accuracy of the pupil decentration data and the failure to obtain repeated findings to establish their reliability did not justify any attempt to compute the intercorrelation of the apparent decentration with the other data obtained in this study. A careful insection of the data did not reveal any apparent relationship of the decentration with the other variables studied. It is conceivable, however, that such a relationship might be demonstrated under more rigorous testing conditions.

The correlation between angle lambda and the spherical equivalent refractive error was determined to test the validity of the statement found in Donders[2c] and Emsley[15] that the visual line cuts the cornea more nasally (positive angle lambda) in hypermetropia and less nasally even temporally (negative angle lambda) in myopia. The low correlations obtained here make it very unlikely that there is any such linear relationship between these two variables.

The finding of means for refractive error which differ significantly from large sample means such as that of Stromberg[16a] and Stenstrom[16b] indicate that in so far as refractive error is concerned this sample is biased toward myopia. This bias would not be expected to affect the foregoing statistical analysis other than the relative position of the scattergram of angle lambda compared with refractive error on a population scattergram of these variables.

SUMMARY

The mean angle lambda in 55 subjects (110 eyes) was found to

be +1.4 degrees. The right eyes averaged +1.1 degrees with a standard deviation of 1.6, and the left eyes averaged +1.6 degrees with a standard deviation of 1.6. The difference between the two eyes was not signficant. These means do each differ significantly from the commonly assumed classical value of five degrees.

The mean residual astigmatism in 44 subjects (88 eyes) was found to be +0.57 D. with a standard deviation of 0.54 for the right eyes and +0.59 D. with a standard deviation of 0.41 for the left eyes. These values are in substantial agreement with those obtained by other investigators.

The Pearson product-moment correlation, r, between these two variables in 44 subjects was determined to be —0.15 for the right eyes and —0.27 for the left eyes. These coefficients are not significantly different from zero at the five per cent level of confidence.

Incidental observations were made relative to the reliability of the testing techniques, some of which are used routinely in clinical work.

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PROXIMAL FACTORS IN CONVERGENCE*

A THEORETICAL CONSIDERATION

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The zone of single binocular clear vision can be specified by five fundamental variables: (1) the distance phoria, (2) the ratio, (3) the amplitude of convergence, (4) the positive fusional convergence amplitude, and (5) the negative fusional convergence amplitude. This specification of the zone, as set forth by Fry,[1] utilized the convergence components originally designated by Maddox.[2] Both these authors were fully aware of proximal convergence, but they appear to have included this variable as a component of accommodative convergence. Data are now available from a number of sources[3-9] which are in sufficient agreement to allow the introduction of proximal convergence as a quantitative factor. Ogle and Martens[9] have introduced the term, proximal convergence—distance ratio (PCA) to designate this quantitative relationship between proximal convergence and the testing distance expressed in diopters. Since the proximal convergence is not related to accommodation,[4, 5, 8] but rather to the testing distance, it is suggested that the abbreviation be written thus PCT, where T is the reciprocal of the testing distance given in diopters.

Ogle and Martens suggest that the PCT ratio is a linear function on the basis of data taken on twenty-eight subjects. Alpern' data[8] on eleven subjects cannot all be fitted with straight lines, but for the purpose of this discussion it will be assumed that the PCT ratio is linear and also that the ACA' ratio is linear (the prime will be used throughout this paper to designate the response values, whereas the unprimed letters will be used to designate the stimulus values.)

Table I summarizes some of the data which have been reported in the last decade and a half. The PCT ratio can be computed in a number of ways. One method is to subtract the ACA ratio as determined by keeping the test distance fixed (so-called gradient method) from the ACA ratio as determined by changing test distances. Ogle and Martens[9] used this method for part of their study. They used a second method

*Submitted on May 22, 1959, for publication in the July, 1959 issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

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TABLE I

Investigator	Number of Subjects	T	Mean PCT	Number of Subjects having Negative PCT
Alpern (Acc. Meas.)	11	.17, .50, 1.00, 1.50, 2.00, 2.50, 3.00, 3.50, 4.00, 4.50 and 5.00	0.7Δ/D	1
Hofstetter (1951)	21	0 and 3.00	0.87Δ/D	2
1942 (Acc. Meas.)	28	0 and 3.00	0.7Δ/D	2
Morgan 1944	50	0 and 2.50	1.2Δ/D	(ten subjects = 0)
1950	413	0 and 2.50	1.4Δ/D	?
Ogle and Martens	28		0.9Δ/D	4
(Fix. disp.)	104	0 and 3.00	1.52Δ/D	17
Schapero and Levy	8	0 and 3.00*	1.0Δ/D	0

*Schapero and Levy used other test distances, but since they did not measure the accommodative response, only the 3.00 diopter test distance has been entered in the Table.

involving binocular fusion (fixation disparity) which gave the highest value of the PCT ratio. Since prism vergence is involved, another factor may be introduced. As the testing distance decreases, the phoria line shifts, the amount of shift per diopter of testing distance change is a third way of computing the PCT ratio.

Alpern and Hofstetter (1942) measured the accommodative response and it will be noted that the values of the PCT computed from these data are the lowest of those shown in Table I.

In his 1951 paper Hofstetter found that the base-in and base-out blur points did not shift the same amount as the phoria line and he suggested that fusional convergence and proximal convergence may interact in some way. This explanation would apply in the fixation disparity method also since this method involves the introduction of fusional convergence by prism vergence stimuli. Apparent distance changes are readily observed during prism vergence testing. During base-out vergence the test target appears to shrink and approach, while during base-in vergence the test target appears to enlarge and recede. The following model attempts to account for these effects quantitatively.

In the following:

C = total convergence
C_t = tonic convergence
C_a = accommodative convergence
C_p = proximal convergence
C_f = fusional convergence

then we can write the total convergence

$$C = C_t + C_a + C_p + C_f. \qquad (1)$$

C_t is the distance phoria measured with the target placed at a

great distance and accommodation relaxed. The others may be expressed as follows:

$$C_a = kA'$$
$$C_p = jT$$
$$C_f = Do\ (1 + Tj_1)$$

where $k = ACA'$ measured with the target distance constant and the accommodative stimuli changed by means of lenses,

A' = The accommodative response,
j = PCT as defined above,
T = reciprocal distance of the target given in diopters,
Do = the vergence stimulus at blur (break) as determined at distance. This is positive for base-out vergence and negative for base-in vergence, and
j_1 = fusional vergence proximal factor. It may have different values for base-in and base-out vergences.

Now we may write the total convergence under any stimulus conditions as

$$C = C_t + kA' + jT + Do\ (1 + j_1T) \qquad (2)$$

The model presented here assumes that fusional convergence has two components, namely positive and negative.

Applying equation (2) to Hofstetter's average data[4] one finds two values for j_1. The base-in value is approximately 1/21, the base-out value is approximately equal to 1/6. It has been this author's subjective observation that the proximal effect during prism vergence is stronger in the base-out direction and hence, the different values may be justified. Certainly the available data is not extensive enough to accept these magnitudes and differences as being valid.

Hofstetter[4] has suggested an alternative hypothesis, which might permit a single valued factor to represent the interaction between fusional and proximal convergence. This hypothesis suggests that there is only positive fusional convergence having the base-in blur as its "zero level." It seems to this author that positive and negative fusional convergence distinct functions, operating to correct phorias at various fixation distances. One is initiated by uncrossed diplopia or fixation disparity, the other by crossed diplopia or fixation disparity.

In Table I the number of cases in which a negative j was found has been tabulated. These represent about ten per cent of the total cases reported. It seems reasonable to assume that these are not artifacts of any kind. Perhaps there may be cases demonstrating negative j_1 values. If there be such cases, these may be poor cases for base-out training, and good cases for base-in training. The fact that base-out training is so

universally successful may argue against any negative values of j_1.

It is a fairly common clinical observation that some heterophorias will continue to persist even after corrected by prisms. It may be that these cases have their distance judgment so deeply intrenched in a given value of fusional convergence at each stimulus distance, that the oculomotor coordination mechanism resists change.

Conjuncturing further, Alpern and Wolter[10] have suggested that the extra ocular muscles have a dual innervation. It may be that the jT factors do arise somewhere in the depths of the autonomic nervous system and are distinct (neurologically) from the kA′ factor.

It seems reasonable at this time to add proximal convergence as the sixth fundamental variable in the relationship between accommodation and convergence and it may not be out of order to suggest that fusional proximal convergence be added as a seventh fundamental variable.

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REFINEMENTS IN CONTACT LENS ADJUSTMENTS TO INCREASE WEARING TIME*

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With the present-day small contact lenses, patients as well as optometrists expect and hope to obtain all-day wearing time. In a great majority of cases, this desire is realized. In fact, with recent improvements in the manufacture and fitting techniques, all-day wearing should be obtainable in most cases.

What then, are the reasons why some patients, even with high motivation, cannot seem to attain comfortable all-day use of contact lenses? The purpose of this paper is to highlight some of the common factors, which tend to reduce wearing time. In most cases, the difference between an eminently successful case and one which is only partially satisfactory, is due to some slight adjustment, which could be done in a matter of a few minutes right in the optometrist's office. It is the close attention to minuscule details which generally makes the difference.

It is therefore becoming increasingly important and necessary for the optometrist who does a considerable amount of contact lens work, to be equipped and able to make these minor lens adjustments right in his office. Increased patient satisfaction as well as fewer office visits will result in direct proportion to the adjusting skill of the practitioner.

Fitting the proper base-curve is certainly an important and primary requirement, but that is only the beginning, not the end of a good fit. The edges of a finished lens are just as important to the comfort and successful wearing, as any other factor in the fitting of a lens. Many a case, which is fitted with a proper base-curve and diameter, can still become a failure when poorly finished edges exist.

The new treatment of the lens edges known as "Con-lish" is an improvement in the attempt to standardize edge finishing. But if it is improperly or carelessly done, there may still be serious edge symptoms that will limit wearing time and cause discomfort.

Another common cause of discomfort is unmatched edge thickness. When such a disparity exists in a pair of lenses, the thickest edge

*Read before the annual meeting of the American Academy of Optometry, Section on Contact Lenses and Sub-Normal Vision, Boston, Massachusetts, December 16, 1958. For publication in the July, 1959, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
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will always produce more lid sensation. Even when there is a marked difference in lens power required between the right and left eye, every effort must be made to equalize the edge thickness. Every pair of lenses should be carefully inspected for radius, power, diameter, thickness and edges before placing in a patient's eye. The edges and bevels, especially, must be carefully examined under high magnification to determine if the lenses have been properly edged and polished. The edge defects will generally be seen better by reflected rather than direct illumination. Many defects may be seen with a simple monocular jeweller's loupe, if the contact lens is held at an angle just under an ordinary desk lamp. Tool-marks, serrated edges and evidence of poor polishing, will often be observed by this method and yet be missed when observed with a binocular loupe.

The base-curve is important since it represents the optical zone or that part of the lens which is in intimate relationship with the apex of the cornea. Thus from that central area, out to the periphery of the lens, the radius must be graduated or adjusted to rest easily on the flatter or peripheral area of the normal cornea. Bi-curves or tri-curves may be incorporated when the lens is ordered, or multi-curve blending may be done with polishing laps in the adjusting kit right in the optometrist's office. The writer has found it more satisfactory to make these adjustments, as needed, in the office while the patient is present. Then, on subsequent checkups, further adjustments may be made whenever indicated by the follow-up K readings or fluorscein patterns.

It is best to take the follow-up K readings immediately after the lenses have been worn continuously from 5 to 8 hours. These new K readings should then be compared with the original or pre-fitted K readings. If the new readings show an increased convexity of the cornea, it is obvious that swelling has taken place and the lens is too steep or tight at the periphery. In such a case, a third or multiple curve should be blended in at the periphery of the lens.

A corneal change of this character could also be caused by a too sharp transition or "shelf" at the peripheral or outer curve. When this occurs, the "shelf" must be blended by polishing with a lap with a radius somewhere between the two curves which cause the sharp transition.

A typical case of corneal oedema would be shown by K readings as follows:

Original or pre-fitted K readings
O.D. 42.00 D.
O.S. 42.00 D.

K readings after 7 hours continuous wearing of lenses

O.D. 43.50 D.

O.S. 44.00 D.

Usually corneal aberation will also be manifested. This would show that the right cornea had swollen to the extent of +1.50 added convexity and the left even more to the extent of a +2.00 increased convexity. The patient's symptoms may or may not be severe, but the need is obvious for an adjustment to flatten or polish in a blending curve at the periphery. The patient will invariably report more comfort and increased wearing time after the adjustment.

When the follow-up reading shows a marked flattening from the original prefitted K reading, it would indicate the opposite of the first example. The lens which had been worn is too flat. Corneal aberration may also be seen in this case or a marked shift in the axis may be present. This would indicate that a lens with a steeper base-curve is needed.

A typical reading to demonstrate this type of case follows:

Original or pre-fitted K reading

O.D. 42.00 H 44.00 V = +2.00 x 90

O.S. 41.50 H 44.00 V = +2.50 x 90

K reading after lenses worn 7 hours

O.D. 41.00 H 43.50 V = +2.50 x 70

O.S. 40.50 H 43.50 V = +3.00 x 105

With corneal aberration on both eyes, this would indicate a marked flattening of the corneal base-curve with an increase in cylinder and a marked shift in axes, accompanied by aberration. Lenses which seat eccentrically on the cornea will in many cases cause aberration and may be observed in the follow-up K readings. The decentering can be either in the vertical or horizontal meridian and produce a distorted K reading. Usually better centering may be obtained with lenses tighter, larger or both. Any case in which marked spectacle blurring persists for longer than an hour should be re-checked for K readings. The cornea will most likely show pronounced changes in curvature from the original K readings. The keratometer or ophthalometer, if used to its fullest potentialities, can become the most valuable instrument available in contact lens work. The clues to most fitting problems generally will be revealed, if one will learn to interpret and compare the readings.

178 NEWBERRY STREET
BOSTON, MASSACHUSETTS

AMERICAN JOURNAL OF OPTOMETRY
and ARCHIVES *of*
AMERICAN ACADEMY OF OPTOMETRY
Established 1924

Vol. 36 July, 1959 No. 7

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Annual Subscription, United States and Canada, $8.00 in Advance; Foreign, $9.00: Single Copies 80c

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Published Monthly by the
AMERICAN JOURNAL OF OPTOMETRY PUBLISHING ASSOCIATION

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PROBLEMS CAUSED BY HEARING AID SPECTACLES

Robert Edgell, publisher of THE HEARING DEALER and secretary of the *Hearing Aid Industry Conference* presents the following report to hearing aid dealers in the June, 1959, issue of that publication:

We understand that a hearing aid manufacturer is making an offer to supply free frames and lenses to hearing aid dealers who purchase the firm's eyeglass hearing aids.

This could lead to serious trouble for our entire industry. We strongly recommend that you avoid this or any similar type of promotion.

In the first place, we all know there is nothing free anywhere: we pay in one way or another. The real point of concern here, however, is that this will surely lead to trouble with the various state optical authorities and licensing commissions.

The threat of licensing is the most serious problem facing our industry today, in my opinion. The area where licensing can gain a foothold—and rapidly so—is in the area of conflict or possible conflict with the optical field. In several states the hearing aid industry came close to falling under licensing legislation that could have practically put the dealer out of business. In both Connecticut and Virginia this conflict between the optical field and the hearing aid field was resolved by the hearing aid dealers agreeing that they would not get involved in the dispensing of eyeglass frames and lenses—that the dealer would fit the hearing aid and then send the customer to an optical specialist of the customer's choice. The dealer also agreed he would send his work only to qualified licensed optical specialists.

This was not passed as law. It rather was a mutual agreement—and this practice is being followed. We understand the situation is working out most satisfactorily for all concerned.

You may feel this is of no concern to you because there has been no problem in your state. However, this is a problem for everyone in our industry. One of the dangers of licensing is that if restrictive legislation is passed in one state, it certainly can be expected to follow in others.

That's why we urge you to leave the optical work to those who are specialists in that field. The hearing aid business is better off today than ever before; devote your time and effort to your own field to do a better job of serving the hard of hearing public.

It is to be hoped that this advice will be followed as it parallels the suggestions approved at the annual meeting of the American Optometric Association in Washington, D.C., in 1958.

Up to the present time optometrists have rather generally stayed away from this activity, yet we note in many urban centers that a growing number of hearing aid dealers have added optical dispensing as a side line to the sale of their hearing aid products and that a growing number of dispensing opticians are now advertising and selling hearing aids along with frames and lenses. Just where the thousands of ethical optometrists will be left in this picture remains to be seen. The present situation is made to order for future trouble and perhaps calls for a nation wide conference of responsible leaders from optometry, dispensing opticianry and the hearing aid industry to lay plans to solve the problems brought into being by the distribution of hearing aid spectacles.

CAREL C. KOCH

CORRESPONDENCE

STEREOSCOPIC ATTACHMENTS FOR PHOROPTER AND REFRACTOR

To the Editor:

The advantages of the phoropter and the refractor have long been recognized. The facility with which lenses are changed, the myriad of lens combinations, the convenience of prismatic additions with Risley prisms, are all inherent in these instruments. These same advantages would be most desirable in a stereoscope. I have designed and developed a sterescope attachment for the phoropter and the refractor which temporarily converts them into a most useful orthoptic instrument.*

The construction and design of the instrument is relatively simple. I have developed the initial working model on the Greens' Refractor using the Stevens phorometer in which the prisms were placed in a

*The Phoropter by American Optical Company and the Green's Refractor by Bausch & Lomb Optical Company.

base-out position. The amount of this prismatic addition was chosen for convenience. Although it differs slightly from the amount of prism in many of the stereoscope-type of instruments now used, I have found that the effectiveness of the instrument is not altered. In the final design a turning device, similar to the cross-cylinder cell, will be added to the Stevens phorometer so that the axis of one of the prisms can be turned 90 degrees, independently of the other prism, yet retaining the full use of the Stevens phorometer. Comparable results may be obtained in the phoropter by using the Risley prisms to supply the prismatic addition.

The additional refractive power is introduced by using the auxiliary lenses provided for static retinoscopy and a gross +4.00 D. addition over the patient's distance prescription. This additional power is slightly more than that used on other stereoscopes. I have found that this is not a deterring factor.

The slide holder was designed so that it would readily slip into the card holder of the refractor and phoropter and would automatically be centered. The lighting system is attached to the card holder and is readily adaptable to an adjustable flashing unit which is designed so that it can be incorporated into the stand of the hydraulic unit.

Since the interpupillary distance may be adjusted, the field of view through the refracting instrument is not a problem. In practice, I have found the instrument convenient to use and easy to incorporate into the refractive and orthoptic techniques.

NORMAN J. WEISS, O.D.

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SPECIAL REPORT

OPTOMETRY AND AUDIOLOGY*

Kenneth O. Johnson†
American Speech and Hearing Association
Washington, D. C.

Some of the problems faced by the American Academy of Optometry and the American Speech and Hearing Association have, of recent months, had interesting and important similarities. This paper has three purposes: It is intended first to provide some background information about the American Speech and Hearing Association, what it is and what it represents; second, to describe briefly the rationale for the current professional approach by audiologists in this country to the evaluation of the amplification needs of hearing handicapped persons; and third, to detail some of the concerns which the American Speech and Hearing Association has for the ethical practices of its members and the clear and firm position taken in these matters.

The American Speech and Hearing Association was founded in 1925. Formal conventions have been held since that date. The professional area represented by our association developed slowly so that by 1951 there were fewer than 2,000 members. By July, 1958, the association had approximately 5,000 members with an anticipated annual increase of about 600 for the years immediately ahead. Perhaps the most significant evidence of the extraordinary growth of interest in this field is the fact that at the 34th annual convention just completed more than 2,500 persons registered. The association, in its early years, was concerned almost exclusively with the area of speech disorders. Through the years the interests of the association and its area of professional activity have expanded. It is now concerned with hearing disability, speech disability and language disability. It is equally concerned with the basic scientific study of the processes of individual human speech and hearing and with the individuals who contribute the fundamental research to this largely clinical activity.

The American Speech and Hearing Association began publishing a quarterly scientific Journal in 1936. It now publishes two journals, the

*Read before the annual meeting of the American Academy of Optometry, Boston, Massachusetts, December 14, 1958. For publication in the July, 1959, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Ph.D., Executive Secretary.

JOURNAL OF SPEECH AND HEARING DISORDERS and the JOURNAL OF SPEECH AND HEARING RESEARCH and plans have been made to publish a monthly journal as the third major publication of the association. The association has accepted the responsibility, as must all professional organizations of consequence, for standards of training, for standards of minimum competence of clinical personnel and for standards of ethical and professional practices.

As stated, we currently have approximately 5,000 members. These individuals make their contribution in a wide variety of settings or contexts. A large percentage of them are members of university or college faculties. A significant number work in public schools. Many of our members work in clinical facilities established in universities and colleges or in community and hospital centers. Other of our members work in clinics established by federal agencies and some serve within industrial environments. These individuals function in a variety of ways. Some of them are teachers, some serve as therapists or clinicians, some provide diagnostic services and some tend exclusively to research or administration in this field. The cohesive element, regardless of the kind of service performed or the context in which it is carried out, is that there exists a basic concern for communication and associated disability.

Professional services in the field of communicative disorders are provided frequently through speech and hearing centers and, to a limited extent, private practice. These centers or clinics are now widespread in this country. There are perhaps more than 250 such clinics providing nonmedical services to hearing-speech-language handicapped children and adults. A large number of these facilities are supported by community funds, either through the Community Chest or Easter Seal organizations. Support in addition to that derived from fees for clinical services has been found necessary for the large majority of these centers because, as we are all aware, habilitation, rehabilitation and research are costly activities and seldom self-supporting.

Many of our members are concerned more or less exclusively with the field of Audiology. Audiology, though variously defined, has come to be recognized as a clinical activity concerned with audition and auditory disability. This area of specialization developed during World War II and is, in effect, an amalgamation of the contributions of many specialties including those of psychology, otology and education of the deaf. The optometrist relates to the American Speech and Hearing Association because of his recent interest in a particular aspect of the field of audiology. The common interest is the hearing aid. The

audiologist has found the hearing aid to be a key to the total rehabilitation of many hearing handicapped persons. Some optometrists have, of recent months, seen the hearing aid, when included in spectacles, as a natural extension of the practice of optometry. Since the hearing aid has created some clinical and ethical difficulties for the audiologist it may be of importance to the optometrist if we here discuss some of these problems.

Audiological services are, as a rule, provided through hearing and speech centers. The functions of these centers vary but the common purpose is to provide diagnostic and rehabilitative services to hearing and speech handicapped children and adults. Patients are referred to these centers by physicians, principally otologists. Some of these centers have pre-school programs for the deaf and children with other communicative disorders. A service common to many of the centers and the one of greatest interest to the optometrists is the hearing aid evaluation. The hearing aid evaluation service was developed to help the patient find answers to the following questions: "Do I need an aid?"; "Will I be able to benefit enough from an aid to warrant its purchase?"; "In which ear should the aid be worn?"; "What type of aid should I use?"; "Will binaural amplification result in significant advantages?"; "Will an aid with frequency response 'A' provide greater assistance than an aid with frequency response 'B'?"; "What educational services such as lip reading, auditory training or speech correction will be helpful?"

These and a number of other important questions perhaps best describe what a hearing aid evaluation service attempts to do. Perhaps also these questions indicate why hearing aid salesmen are not in a position to satisfy the needs of all hearing handicapped persons. The hearing aid service provided by these centers includes a highly technical evaluative activity requiring the attention of the professional audiologist. If, after the initial examining procedures, it is found that the use of amplification should result in an increase in social efficiency, a variety of hearing aids are tested on the patient and on the basis of comparative scores obtained a given hearing aid with a particular receiver is recommended. That is, the patient is advised to go to the local hearing aid dealer and purchase a hearing aid of the type found to be most helpful during the evaluation.

While there is substantial controversy in our field concerning the validity of some of the procedures involved there is little question as to the ethical problems attending this activity. It is important to note that these centers collect fees for services performed but do not sell the

hearing aid. The patient who has been found to be in need of a hearing aid is referred to a hearing aid salesman or dealer or to more than one hearing aid salesman or dealer as the case may require and the test results indicate. The patient may or may not accept the recommendation given to him at the center and, in some instances, never proceeds to the important step of his rehabilitation which is the purchase of a hearing aid from a hearing aid salesman. If, however, he does go to the dealer the sale of the hearing aid is the sole responsibility of the salesman and all profit derived is the dealer's. The center receives no part of the funds obtained from the sale of the hearing aid nor in any way profits from the recommendation made.

Hearing aid evaluation procedures developed in this country largely because it was found that no *single* hearing aid provided either subjective satisfaction or maximum benefit as measured by objective means for *all* hard of hearing persons. Some individuals were found to perform "better" with transmitter "A" and receiver "X" while others were found to perform better with transmitter "B" and receiver "Y." Hearing aids vary markedly according to several characteristics. For example, they vary according to gain, maximum power output and frequency response. Some transmitter and receiver combinations reproduce well the high frequency sounds while other combinations reproduce well the low frequency sounds. It is a characteristic of human hearing in the majority of cases that deficiency increases with frequency, i.e., as we develop hearing loss we most commonly have greater loss for the higher frequencies. If we recognize that hearing loss is seldom uniform and that the manufacturers constructed hearing aids in such a way that the frequency response of the aid might complement or match the hearing loss of the person it may be considered logical that hearing aid evaluation procedures developed as an effort to determine by objective means which hearing aid with which receiver would provide the maximum benefit. The goal of the hearing aid evaluation service is to assist the patient to function in this very verbal society with the greatest possible efficiency.

Efforts to predict, on the basis of the diagnostic examination alone, which transmitter and receiver combination would provide maximum benefits were unsuccessful and, as a consequence, a laborious trial-test method was devised. The trial-test method or hearing aid evaluation is a time consuming procedure averaging perhaps 1½ to 2 hours and involving elaborate electroacoustic equipment and sound isolated rooms. We need not discuss here the details of the hearing aid evaluation procedure per se. Suffice it to say that the same tests under the same condi-

tions are given with a variety of transmitter and receiver combinations to a given patient and the results are compared one to the other and against the basic performance information obtained without the use of an aid. On the basis of the comparative information the recommendation is made.

During the past few months I have received several letters from optometrists suggesting that hearing aids should be prescribed by them. They did, of course, indicate that their basic motive was to protect the public. In view of this recent interest which some optometrists have shown in the matter of the dispensing of hearing aids it will not surprise you to learn that a few audiologists also came to the conclusion that the audiologist should be permitted to profit directly from the sale of the aid. The plan devised permitted the continuation of the objective evaluation of hearing aids as conducted in the average center but included the direct sale to the patient of the hearing aid recommended on the basis of the evaluation. Such an arrangement permitted the profit from the sale of the aid to accrue to the individual audiologist.

At this point and on the urging of its audiologists the American Speech and Hearing Association approved two additions to its code of ethics. One addition specifically prohibited members from selling hearing aids and the other addition stated that it was unethical for a member to permit his professional titles and accomplishments to be used by others for the promotion of hearing aid sales or the sale of other audiological instruments. With these additions to the code the position of the association was clear. It is the intention of the association that members of this profession shall earn their living by service and not through the sale or promotion of a product. Following the addition of these two sections to our code of ethics a few individuals found it necessary to withdraw membership but the large impact from this action came in the form of overwhelming approval from the membership. At the same time the direction for the future development of the field of audiology was clarified. In addition, improvement was noted immediately in our relations with both hearing aid dealers and manufacturers. The distinction between commercial and professional audiological activity was clearly stated.

The audiologist and otologist have had in general reasonably satisfactory relations. The relationship developed because there has been a growing appreciation and understanding of the responsibilities and contributions of the separate specialties. The growing competition between the hearing aid dealer and the audiologist was helped a great deal by the code additions. The relationships now established, if retained, should

provide a most hopeful future for the hearing handicapped person in our society.

The rationale for the additions to our code may be of some interest to the optometrist. It is not possible to discuss in complete detail some of the subtle, though critical, ramifications of this matter which prompted the association to take its stand. Only the basic issues may be presented here. First, and sufficient by itself, is the determination of the American Speech and Hearing Association that the professional contribution of its clinical members shall be to render service to individuals handicapped by disorders of communication and that their income may be derived from the rendering of this service and not from the profit obtained from the sale of a product. Second, a distinguishing characteristic of the professional person is objectivity. When professional judgment is subject to however slight a degree to the important influence of relative profit a hazard exists which may affect objectivity. The relative profit derived from the sale of various hearing aids is well known. The public assumes objectivity in the professional person and it is a fundamental obligation of the organization representing the profession to protect the interest and trust of the public. Any situation or circumstance which encourages bias and represents a threat to objectivity should be curtailed. The significance of the profession to the public as well as to the members themselves depends in large part on the degree to which objectivity is protected. These were the basic reasons which prompted the additions to the association's code of ethics. The codes which govern optometry are, it would appear, designed to accomplish the same end as are the additions to our code as described above. We came to essentially the same end point from quite different beginnings.

It is my hope that this discussion of the purposes of the American Speech and Hearing Association, the rationale for current hearing aid evaluation procedures conducted by audiologists and the basis for the present code of ethics of our association have shown important relationships between optometry and audiology. There are many problems which face the optometrist or the audiologist who seeks to profit from the sale of hearing aids. During recent months I have had an opportunity to discuss this matter with leading audiologists and optometrists. I think all would agree that the most important consequence of commercialism in either optometry or audiology would be the loss of the profession itself.

1001 CONNECTICUT AVENUE
SUITE 532
WASHINGTON 6, D. C.

CURRENT COMMENTS

Terry Judith Parkins
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department; such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

DE VERE HEADS AMERICAN OPTOMETRIC ASSOCIATION

At the annual Congress of the American Optometric Association, Statler Hilton Hotel, Dallas, Texas, July 1, Dr. P. N. DeVere, Morganton, North Carolina, president-elect for the past year, took over the top spot from Dr. Hoyt S. Purvis, Jonesboro, Arkansas. Dr. Purvis will now serve on the Board of Trustees as immediate past president. Others elected as officers and trustees are: Dr. Richard C. Schiller, Marshalltown, Iowa, president-elect; Dr. Don A. Frantz, DeKalb, Illinois, vice-president; Dr. H. Ward Ewalt, Pittsburgh, Pennsylvania, secretary-treasurer; Dr. J. Herman Thomas, trustee; Dr. C. R. Haser, Butte, Montana, trustee; Dr. Melvin B. Dunbar, Lebanon, New Hampshire, trustee, and Dr. Roy M. Swain, Ukiah, California, trustee.

During the convention the Beta Sigma Kappa Gold Medal Award was presented to Dr. Don R. Paine, Topeka, Kansas, and to Dr. Lester Sugarman, Meriden, Connecticut, for their outstanding contributions to the optometric profession. These presentations were made by Dr. Glyndon Rowe, Dearborne, Michigan, Chancellor of the World Council of Beta Sigma Kappa.

During the Congress the American Optometric Foundation held its 13th annual meeting. Dr. William C. Ezell, Spartanburg, South Carolina, was re-elected president. He announced a $14,000 research project in the field of motorists' vision and highway safety to be started during the coming year at Indiana University.

Approximately 1,150 persons were registered at the Congress which was reported as being one of the most successful in recent years. The 1960 A.O.A. Congress will be held in Atlanta, Georgia.

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Dr. Sheard was formerly editor of the *American Journal of Physiological Optics* and for many years director of the Department of Biophysics, The Mayo Foundation. The book contains 83 illustrations, 476 pages, $15.00.

CONTENTS

SECTION ONE – Selections from Editorials and Short Essays. SECTION TWO – Dynamic Ocular Tests. SECTION THREE – Dynamic Skiametry and Methods of Testing the Accommodation and Convergence of the Eyes. SECTION FOUR – Considerations Regarding the Analysis and Interpretation of Data on Ocular Accommodation and Convergence; Zones of Ocular Comfort. SECTION FIVE – Ophthalmic Optics with Applications to Physiological Optics. SECTION SIX – Ocular Photosensitivity and Dark Adaptation. SECTION SEVEN – Personalia.

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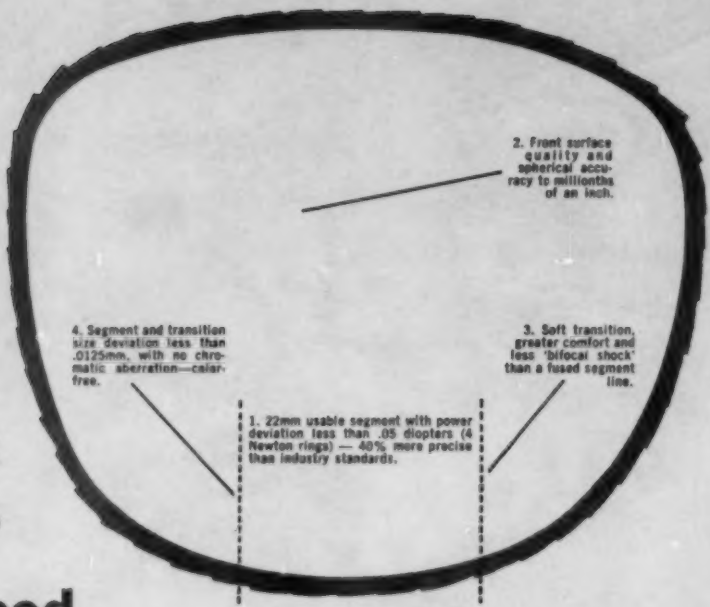
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